AN

EXPERIMENTAL INVESTIGATION

INTO THE

FUNCTIONS OF THE EIGHTH PAIR OF NERVES,

OR THE

GLOSSO-PHARYNGEAL, PNEUMOGASTRIC, AND SPINAL ACCESSORY. *

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The Eighth Pair are undoubtedly the most interesting and important of all the nerves of the body, both in a practical and theoretical point of view. Their lesions are attended by the most serious derangement of the respiratory and digestive processes, and bear in a prominent manner upon some of the principal doctrines in physiology. The functions of these nerves have, therefore, commanded a more than ordinary degree of attention, and the industry and talent of numerous observers have been directed towards their elucidation. In entering upon an experimental investigation into the functions of the three divisions of this pair of nerves, I was fully aware of the numerous difficulties attending such an undertaking, and have endeavoured to approach it with all the circumspection and assiduity which its importance and inherent intricacies require. I, nevertheless, feel very considerable diffidence in presenting the first results of this inquiry to the pub-

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* A short epitome of this paper was read at the last meeting of the British Scientific Association.

lic, since the data which I have obtained will necessarily lead me to draw several important inferences regarding the functions of these nerves, at variance with those entertained by many of the most celebrated and experienced practical physiologists. And most persons feel disposed to receive with caution or even distrust the observations and opinions of one who can scarcely be said to have finished his novitiate in the difficult task of unravelling the operations of the complicated machinery of the higher organized bodies, and the more especially when a considerable part both of his premises and inferences are in opposition to those promulgated by physiologists, whose years and well-earned fame, acquired by their long and laborious exertions in the extension of this science, entitle their opinions to the highest credit. Being confident, however, from my previous pursuits, and from the great care with which I conducted, after their death, the dissections of all the animals operated upon, that I could not possibly be mistaken as to the particular nerves upon which the experiments had been made; profiting largely from the recorded errors and instructions of those who have preceded me in this field of inquiry; and taking the very necessary precaution of making a careful repetition of the experiments under varied circumstances, so as to avoid as much as possible any accidental sources of error, I have been encouraged to publish the results thus obtained,—being satisfied that the facts will be found, upon actual examination, such, or at least nearly such, as I represent them. In entering upon this investigation I had no favourite theory to defend, stood committed to no preconceived notions, or shackled by any slavish deference to authorities, but was ready and willing to give up any of my former opinions as soon as they appeared to be inconsistent with the phenomena which presented themselves; and I sincerely hope that I am not chargeable with the opposite and equally dangerous fault of seeking and hankering after novelties.

In stating the experiments, I shall enter more fully into the details than many may think necessary, as it appears to me that it is an object of essential moment to mention all the circumstances under which any important experiment is performed in physiological investigations, where so many extraneous circumstances are apt to interfere with the results; and I am convinced that if this plan had been more fully followed, many a controversy might have been avoided, as well as much animal suffering spared, and the science would this day have presented fewer discordant statements, and less unfortunate collision of opinions. It may appear to some that I have repeated many of those experiments with unnecessary frequency, and a wanton sacrifice of animals. But I naturally felt diffidence and distrust in the accuracy of the results which I obtained when opposed to those of more experienced ob-

servers, and it was only after repeated and careful examination of the phenomena, that I could feel myself justified in calling these in question. It is also sufficiently obvious, that nothing is more injurious to the progress of science than hasty and partial observations; and I was anxious to avoid, as far as I possibly could, adding to that mass of conflicting evidence, which there is already so much reason to deplore. Besides, as every false observation requires additional experiments for its refutation, I felt that, with less extended opportunities of witnessing the phenomena under examination, I must incur a greater risk, not only of throwing obstacles in the way of the progress of truth, but also of occasioning a useless infliction of animal pain.

In detailing the following experiments, and the conclusions which I feel inclined to draw from them, I shall follow the order in which the nerves, generally included under the eighth pair, are enumerated, and therefore commence with the *Glosso-pharyngeal.*

Part 1st.—*Glosso-Pharyngeal Nerve.*

The experiments on this nerve were all performed upon dogs, and were twenty-seven in number. Seventeen of these were for the purpose of ascertaining if it were to be considered a nerve both of *sensation and motion*; and what are the effects of its section upon the *associated movement of deglutition*, and on the *sense of taste.* The other ten were performed upon animals, immediately after they had been deprived of sensation, with the view of satisfying myself more thoroughly, how far it is to be considered a *motor nerve.* In cutting down upon this nerve in the living animal, the following plan was adopted after a careful examination of the anatomy of the parts. An incision, varying in length, in proportion to the size and species of the dog, was made nearly parallel to the back part of the base of the *inferior maxilla;* its posterior termination always extending a short distance over the anterior margin of the *sterno-mastoid muscle.* After cutting through the *skin* and *platysma myoides* or *cutaneous* muscle, the two large veins which go to form the *external jugular* were each secured in a double ligature, and cut across between the points tied. The *glands* at the angle *of the jaw* were removed or dissected aside, and the *carotid artery* exposed. The artery was generally first secured in a ligature below the *hypoglossal nerve*, and before it had given off any of its large branches; it was then exposed above the *hypoglossal*, included in a double ligature and cut across. This was found to be the most effectual method of preventing the troublesome hemorrhage, which otherwise is apt to occur from wounding the large arteries, arising from the carotid at this point. After this by a little dissection, the nerve was exposed as it lies upon the lower margin of

the *stylo-pharyngeus muscle*, near its origin from the *styloid process*. One of the best guides in displaying the nerve, is the *osseous expansion* connected with the *tympanic cavity* of the *temporal bone*, which is always readily felt after the *carotid* has been exposed. In dissecting the nerve back to the *foramen lacerum posterius*, great care must be taken to separate it from the *pharyngeal branch of the par vagum*, which lies sometimes in immediate contact with it, at other times one or two lines below, and is frequently united to it by a considerable communicating branch, so that it may readily be mistaken for a large pharyngeal branch of the glosso-pharyngeal. I am afraid, for reasons to be afterwards stated, that sufficient precautions have not been taken by other experimenters to separate these from each other. This is the more necessary, as I am confident that these two nerves differ very materially in function, and this must consequently have seriously affected the results. The superior laryngeal branch of the *par vagum* is placed a short distance below these two nerves, but was rarely seen except when exposed designedly. I have observed very considerable differences in the manner in which the glosso-pharyngeal gives off its branches to the pharynx and fauces: sometimes it begins to give off small filaments soon after it has emerged from the base of the cranium, and continues to give off a number of small branches in succession, until it has furnished all the filaments to the pharynx and fauces; more commonly the nerve forms a sudden enlargement upon the lower margin of the osseous expansion of the tympanic cavity, from which the principal branches to the pharynx and fauces are given off, one or two of which are much larger than the others. It is almost needless to add, that in all the animals kept alive, after section of these nerves for subsequent observations, a considerable portion of the trunk of each nerve was removed. The first point connected with the function of the nerve to which I directed my attention was the disputed question, whether or not it is to be considered both a *motor* and *sensitive* nerve. In investigating this it has occurred to me, that the discordant results obtained in late experiments may be explained. It is with this object, as well as with the view of pointing out the difficulties I encountered at the outset, that I have here given the details of the first experiments, as they are put down in my notes taken at the time. These may serve as guides to those who may afterwards wish to turn their attention to this subject.

Is the *glosso-pharyngeal* a nerve both of motion and sensation?

Exp. I. June 3, 1837.—The glosso-pharyngeal nerve was exposed on one side in a middle-sized terrier, and irritated by pinching it with the forceps, but no satisfactory evidence either of sensation or motion was observed, even when tied tightly in a

ligature and cut across. When the same nerve was exposed on the opposite side, a powerful and sudden convulsive movement of the muscles of the throat and lower part of the face, followed the first pinch of the forceps. After I had satisfied myself that this could be readily renewed by irritating the nerve, these muscular twitchings of the face appeared to me to resemble so closely those produced by pinching a branch of the *portio dura*, that though confident that the nerve exposed occupied the position of the glosso-pharyngeal, and that no branch of the *portio dura* lay along the lower margin of the stylo-pharyngeus muscle, yet I could not divest myself of the idea that some unusual distribution, or some other cause, had thrown a branch of the *portio dura* in our way. Another nerve, lying immediately below this, and of somewhat smaller size, was exposed, (which was afterwards ascertained to be the pharyngeal branch of the *par vagum*,) and experimented on under the supposition that it was the glosso-pharyngeal. When this nerve was irritated, no distinct contractions of the muscles of the throat were visible; and though the animal appeared to give some indications of suffering when the nerve was included firmly in a ligature and cut on its proximal side, yet these were far from being decisive.

Exp. II.—On exposing the glosso-pharyngeal nerve on one side in a young dog, the same convulsive movements of the throat and face were observed as in the preceding experiment. Being again considerably perplexed whether this could be the glosso-pharyngeal or not, since most of the numerous muscles thus thrown into convulsive action do certainly not receive any filaments from this nerve; while irritation of a branch of the *portio dura*, though sufficient to account for the convulsive movements of the face, could not, however, explain the extensive movements of the muscles of the throat, I tied a ligature loosely around it, to enable me to recognize it readily again, and exposed the nerve lying immediately below, (pharyngeal branch of *par vagum*,) as in the preceding experiment. No convulsive movements were seen on irritating this last nerve, and the indications of suffering were not distinctly marked. The animal was then killed by blowing air into one of the exposed veins, and the anatomy of the nerves experimented on carefully examined, when we were satisfied beyond the shadow of a doubt, that the nerve, the irritation of which was followed by such distinct convulsive movement in this experiment, was the glosso-pharyngeal. On exposing the pharnygeal branch of the *par vagum* and the glosso-pharyngeal on the opposite side in this animal, as soon as it had ceased to breathe, and when the constrictor muscles of the pharynx were much more fully displayed than during the operation upon the animal when alive, distinct contractions of these constrictor muscles were observed

after each pinch of the pharyngeal branch of the *par vagum* with the forceps; while the same irritation applied to the glosso-pharyngeal immediately afterwards, was followed by no visible muscular movement. Being now satisfied that in the preceding experiment we had in the second operation divided the pharyngeal branch of the *par vagum* instead of the glosso-pharyngeal, the animal was killed, and the dissection proved that we were right in our conjecture.

Exp. III.—The nerve was exposed on one side in a small cocker dog affected with the distemper, but no satisfactory evidences of sensation or muscular movements were observed. This might arise from the sickly condition of the animal, or, as we shall immediately show, from the nerve being only irritated anterior to, or on the distal side of that part of the trunk where the pharyngeal branches leave it.

Exp. IV.—The glosso-pharyngeal nerve was first exposed on one side, and then on the other, in a middle-sized terrier. Very forcible convulsive movements of the muscles of the throat and lower part of the face, but more especially of the throat, were observed on pinching these nerves with the forceps. On cutting the nerve across, the same convulsive movements and indications of suffering were noticed on pinching the nerve on the proximal end, or that part of the nerve which retained its natural connection with the *medulla oblongata*. These convulsive movements were exactly similar to those observed when the nerve was entire. There were no convulsive movements on irritating the lower end by the forceps.

Exp. V.—The nerve was exposed on one side in a middle-sized full-grown pointer. When irritated by pinching it firmly with the forceps, only very feeble convulsive movements of the throat were excited, and such as would readily have escaped notice, had we not been in search of them. Professor Sharpey of the London University College, was present from the commencement of this experiment, and as we were proceeding to expose the nerve of the opposite side, we were joined by Professor Alison. On irritating the opposite nerve by pinching it with the forceps, the convulsive movements of the muscles of the throat were distinctly marked, but still in a less decisive manner than in some of the preceding experiments. The nerve was then included firmly in a ligature. On irritating the nerve on the proximal side of the ligature, the same convulsive movements followed; while no effect was observed from the irritation of the nerve on the distal side, or that in connection with the tongue and pharynx. The same difference in the results was also obtained from the irritation of the two ends of the nerve when cut across. We had in this dog an opportunity of contrasting the manner in which muscular movements are induced through the stimulation of a motor nerve, such

as the hypoglossal, or the spinal accessory, with that motion which results from the excitation of a sensation, as appears to be the case when the glosso-pharyngeal is irritated. For while the stimulation of the hypoglossal and spinal accessory on the distal side of the ligature was followed by convulsive movements of the muscles to which they are distributed, and of these only, the stimulation of the glosso-pharyngeal on the same side of the ligature produced no visible effect. On the other hand, irritation of the hypoglossal and spinal accessory on the proximal side of the ligature excited no muscular movements whatever, while excitation of the glosso-pharyngeal on this side was followed by extensive movements in muscles, to the greater part of which it sends no filaments. When the glosso-pharyngeal was pricked with the forceps, the indications of suffering were distinctly but not strongly manifested, but the application of a tight ligature was evidently attended by intense pain,—an effect which we were somewhat surprised to find also attended the application of a tight ligature to the hypoglossal. * A fatal dose of prussic acid was given, and the muscles of the throat more fully exposed, when distinct convulsive movements of the constrictors of the pharynx were observed each time that the pharyngeal branch of the *par vagum* was pricked.

In dissecting the nerves after death, I was anxious to ascertain if any possible explanation could be given, why the convulsive movements attending the stimulation of the nerve should have been so feebly manifested on the side first operated on, and I ascertained that we had been experimenting on the nerve of this side beyond or on the distal side of the origin of nearly all its pharyngeal branches; while in the second operation we had been experimenting on the trunk of the nerve prior to, or on the proximal side of the origin of its pharyngeal branches. Dr Sharpey examined these dissections, and expressed himself satisfied with the accuracy of the statements here given.

Exp. VI.—The nerve was first exposed on the left side in a middle-sized terrier. On pinching the nerve the convulsive movements of the throat were rather feeble, though perfectly distinct. When proceeding to display the nerve on the right side we were joined by Professor Sharpey. We first pricked the lingual branch, by which I here mean the continuation of the trunk of the nerve proceeding to the tongue after giving off its pharyngeal branches, (under the belief that we were operating on the entire trunk) and neither convulsive movements, nor indications of suffering followed. On dissecting the trunk of the nerve backwards towards the *foramen lacerum*, and beyond the origin of the pharyngeal

* Mayer has described a small ganglion on the root of this nerve in the dog and ox. He has seen it once in the human subject.—See Edin. Med. and Surg. Journ. Vol. xliii. p. 486.

branches, distinct convulsive movements of the muscles of the face and throat, and decided indications of suffering were observed. On pricking the nerve during the moaning of the animal, it was several times remarked that the voluntary actions of the muscles of the throat were interrupted by these convulsive starts.

This animal was killed a few days after, and it was ascertained that while the nerve had been satisfactorily divided on one side, one pretty large pharyngeal branch had been left on the other. Dr Sharpey also examined this dissection, and was fully satisfied of its accuracy. The impression on my mind is, that this pharyngeal twig was found on the left side, (the side first operated on,) but as it is not expressly stated in my notes, I cannot positively affirm it.

Exp. VII.—On exposing the glosso-pharyngeal nerve in a stout terrier bitch, we found that irritation of the lingual branch was attended by no visible muscular movements, and no decided indication of suffering; while on irritating some of the small pharyngeal filaments individually, which leave the trunk of the nerve soon after it leaves the *foramen lacerum*, convulsive movements of the muscles of the throat and face, and marked indications of suffering followed.

It will be unnecessary to detail the results of the other ten experiments which were performed to ascertain the effects of irritating this nerve, as far as the indications of muscular movements and common sensation are concerned. I may state, however, that the facts detailed in the above experiments were amply confirmed by those which were subsequently performed. It was found that the muscular movements excited by pinching this nerve varied in degree in different animals, but were always distinctly marked when the precaution was taken to irritate the nerve before it had given off its pharyngeal branches. It was also repeatedly observed, that when the nerve was cut across, irritation of the lower end, or that in connection with the muscles, was followed by no movement; while, on the other hand, irritation of the cranial end, even when the nerve was divided before it had given off a single twig, was followed by as powerful convulsive twitches as when the nerve was entire. We also remarked more than once, that while the pinching of the lingual branch caused no muscular movements, irritation of one of the small pharyngeal twigs was followed by very strong convulsive twitches of the throat and lower part of the face. The capability of this nerve to transmit those impressions which excite *sensation*, was amply proved by the severe and undoubted indications of suffering which in many cases followed the pinching of it with the forceps. In several cases, however, the indications of suffering were much less strongly marked than in others, but that this nerve possesses *common sensation*, in the

usual acceptation of that term, I am fully convinced, not only from the results of these seventeen experiments expressly made upon these nerves, but from five others, where they were exposed in displaying the pharyngeal branches of the *par vagum*. That irritation of the trunk of the glosso-pharyngeal nerve is attended by convulsive muscular movements and indications of suffering, is in direct opposition to the statements of Panizza, * Dr M. Hall, and the late Mr Broughton,† and is in accordance with those of Dr Alcock‡ of Dublin. I was at first fully convinced that these experimenters had been operating on different nerves, though it was difficult to conceive how such mistakes could arise in the hands of those so much accustomed to researches upon the nervous system. The details of Exps. V. VI. and VII. will, I think, however, explain how such discrepancies should arise, without seriously impugning the anatomical knowledge or acuteness of observation of either party. For though I do not mean to affirm that pinching the lingual portion of the nerve is never followed by indications of suffering, (for from the irregularity in the origin of the pharyngeal twigs, and the difficulty of judging at the bottom of a deep wound, at what particular part these are all given off, it is generally impossible to decide when the lingual portion of the nerve may be said to begin,) yet I have no hesitation in saying, that if in these three experiments, and in others not detailed here, we had operated on that part of the trunk of the nerve which first presented itself, and not proceeded to dissect it back towards its place of exit from the cranium, we should have gone away with the impression that the irritation of this nerve was followed by no muscular movement, and little if any indications of suffering. Dr Alcock§ suggests that Panizza may have experimented upon the superior laryngeal branch of the *par vagum*, instead of the glosso-pharyngeal; but we can scarcely believe that an accurate anatomist like Panizza could commit such an error. Besides, in repeated experiments upon the laryngeal nerves (as we shall afterwards more particularly mention,) we found, in all the animals operated on, except two dogs which appeared considerably exhausted by great previous suffering, ample grounds for dissenting from the statements of Dr Alcock, that this nerve is devoid both of sensibility and of muscular influence. With the exceptions mentioned, very severe indications of suffering, and in a few cases also distinct muscular twitching of the neck and face attended the pinching and cutting of this nerve. These muscular twitchings,

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* Edinburgh Medical and Surgical Journal, Vol. xlv. p. 86.

† Dr M. Hall and Mr Broughton in Vol. iv. p. 679, of British S. Association, also Mr Broughton in Vol. xlv. of Edin. Medical and Surgical Journal, p. 429.

‡ Dublin Journal of Medical Science, Vol. x. p. 260.

§ Op. cit. p. 266.

however, were certainly not so frequently observed nor so well marked as those we witnessed from pinching the glosso-pharyngeal.

Can these muscular movements attending the irritation of the trunk of the glosso-pharyngeal nerve arise partly or wholly from the development of one of those impressions which, when conveyed by the sensitive filaments to the central organs of the nervous system cause some influence to be transmitted along certain other motor nerves, by which particular muscles are called into action,—in the same manner as irritation of the trunk of the optic nerve, causes contraction of the iris, and compression of the trunk of the *par vagum* in the neck not unfrequently produces violent movements of the respiratory muscles? Or can it be that these muscular movements depend partly or wholly upon the irritation of the nerve acting directly through its motor filaments upon the muscular bundles to which they are distributed,—in the same manner as pinching of the hypoglossal causes convulsive movements in the muscles of the tongue? Dr Alcock is doubtful on this point. Though "disposed to regard the result in question as the effect of a sentient impression excited through the nerve, and referred to the interior of the pharynx," from the fact, that this movement extends to muscles not supplied by this nerve, and forms an associated action, he yet admits, "that the circumstance may be as well explained by an exalted degree of muscular excitement, or by a higher one than that necessary to produce the simple starting." * In the experiments which I have detailed above, we have, however, sufficient evidence to decide that these muscular movements can only be explained on the supposition that they depend upon some influence transmitted along other nerves distributed to these muscles, and through the intervention of the central organs of the nervous system. We there find, and the facts were still farther confirmed by what we observed in other experiments, that irritation of a single pharyngeal twig, or, what is still more conclusive, of the upper or cranial end of the cut nerve before it had yet given off any of its branches, was attended by as powerful convulsive movements, as when the trunk of the nerve and all its branches were entire and uninjured.

Is this nerve, then, entirely a nerve of sensation, or is it partly motor and partly sensitive?

Mr Mayo,† and Professor Müller‡ of Berlin, maintain that it is both a nerve of sensation and motion,—the former on physiological, the latter on anatomical grounds. "When the *glosso-pharyngeal* nerve," says Mr Mayo, "is pinched in an ass recently

* Oper. cit. p. 265.

† Anatomical and Physiological Commentaries, No. ii. p. 11.

‡ Archives für Anatomie, Physiologie, &c. No. ii. p. 275. 1837. Von Dr J. Müller.

killed, a distinct convulsive action ensues, apparently including and limited to the *stylo-pharyngeus* muscle, and the muscular fibres about the upper part of the *pharynx*." I have already stated in the above experiments that no muscular movements were observed on irritating the lower end of this nerve, when cut across. I attach, however, little weight to this observation, since it was but rarely possible to see distinctly the contractions of the constrictors of the pharynx, from the imperfect manner in which these muscles were exposed in operating on the living animal. As it is agreed, that when a motor nerve is irritated immediately after death, and while the muscular contractility is still vigorous, the muscles to which it is distributed are thrown into contraction, I proceeded, therefore, as in the above experiment by Mr Mayo, to satisfy myself on this point. These experiments were made upon ten dogs, the nerves being exposed immediately after death, and the irritation of the pharyngeal branch of the *par vagum* was always taken as a test that the muscular contractility was still in sufficient vigour to be readily excited through the motor nerves, and also a standard of comparison. I cannot say that the results of these experiments were uniform, but I am convinced that in none of them was there any satisfactory evidence to lead us to believe that the glosso-pharyngeal is a nerve of motion ; and I am perfectly satisfied, that in all of them, which were quite accurately performed, no muscular movements were seen on irritating this nerve. As the experiment is one which requires great care in its performance, and is liable to a marked source of fallacy from the intimate connection of the nerve with another, viz. the pharyngeal branch of the *par vagum*, which is undoubtedly a nerve of motion, I shall relate some of the experiments which illustrate this. Before doing this I may again more particularly refer to the relative position of these two nerves to each other, since this is not mentioned, as far as I am aware, by any previous experimenter. The trunk of the *pharyngeal branch of the par vagum* lies, as we have already stated, quite close to that of the *glosso-pharyngeal*. It divides into ascending and descending branches, the ascending branch (or branches) which passes to the superior constrictor and muscles about the isthmus of the fauces, runs generally immediately behind the trunk of the glosso-pharyngeal for a short distance, and may remain merely in close apposition, or form a free anastomosis with it. Very frequently the trunks of the two nerves anastomose by a short branch a little anterior to the *foramen lacerum*, in which case it generally requires a careful dissection to show that the large descending twig of the pharyngeal branch of the *par vagum* is not a part of the glosso-pharyngeal nerve. In one case which I dissected lately, a communicating branch connected the trunk of the two nerves, before they had fairly cleared the *foramen lacerum*. It is

absolutely necessary to have these facts impressed upon the mind, before any satisfactory experiments can be made upon the glosso-pharyngeal, with the view of ascertaining whether it is a motor nerve or not.

Exp. VIII.—The *glosso-pharyngeal nerve*, *pharyngeal branch of the par vagum*, and *constrictor muscles* of the *pharynx*, were exposed in a middle-sized mongrel, immediately after it had been deprived of sensation by a dose of prussic acid. On pinching the trunk of the glosso-pharyngeal nerve no muscular movements were observed; while on pinching the *pharyngeal branch* of the *par vagum*, immediate and powerful convulsive movements of the *constrictor muscles* of the *pharynx* followed. This was repeated several times on both sides with the same results.

The same phenomena were witnessed in two other dogs, with this additional observation in one of them in which the anterior part of the pharynx was opened, that the muscles about the *isthmus* of the *fauces* as well as the *constrictors* of the *pharynx* were thrown into action on pinching the *pharyngeal branch* of the *par vagum*.

Exp. IX.—The *glosso-pharyngeal*, *pharyngeal branch* of the *par vagum*, and *constrictors* of the *pharynx*, were exposed in a young terrier immediately after a fatal dose of prussic acid had been given. On pricking the glosso-pharyngeal no effect followed, while convulsive movements of the constrictors of the pharynx were very apparent on pricking the pharyngeal branch of the *par vagum*. The wires of a pretty powerful galvanic trough were then applied, and it was observed that when proper precautions were taken to insulate the glosso-pharyngeal, so as to avoid the passage of a current through the muscles, no movement was seen, while very powerful convulsive movements of the *pharynx* attended each application of the wires to the *pharyngeal branch* of the *par vagum*. The nerves of the opposite side were then exposed. At the first application of the galvanic wires to the glosso-pharyngeal no movement followed. On repeating the application, slight irregular movements were observed in the middle *constrictor*, where many of the *pharyngeal* branches of the glosso-pharyngeal seem to plunge themselves. The same extensive and vigorous movements, as were observed on the opposite side, followed each application of the wires to the *pharyngeal branch* of the *par vagum*. We were afterwards satisfied that the slight convulsive motions seen on irritating one of the glosso-pharyngeal nerves in this experiment, could be accounted for by the transmission of a slight current through the muscle, for in this case the trunk of the nerve was not cut across, but merely raised on an aneurism needle. Now Mr K. T. Kemp (whose practical acquaintance with every thing relating to galvanism is well known) to whom I referred the

question, stated to me that it was perfectly possible, nay probable, that a part of the galvanism generated by a battery of twelve double plates, each five inches square, such as was used in this experiment, would, instead of passing across between the two wires, take the more circuitous course along the circle, which was formed through the muscle by the conducting nerve and cellular tissue. In fact, we had demonstrative evidence that such was the case in this experiment, for my friend Dr J. Duncan, pointed out at the time, that if the aneurism needle was allowed to touch the sterno-mastoid muscle, strong convulsive movements of this muscle were excited, though the needle was placed under the nerve a little posterior to the part where the wires were applied.

Exp. X. — The *glosso-pharyngeal nerve*, *pharyngeal branch* of the *par vagum* and *constrictor muscles* of the *pharynx* were exposed in a young dog immediately after it had been deprived of sensation by a fatal dose of prussic acid. Distinct convulsive movements of the muscles of the pharynx were seen when the pharyngeal branch of the *par vagum* was pricked by the forceps; no visible movement when the glosso-pharyngeal was similarly treated. The nerves were then cut across, and galvanism applied with the same results. The same observations were made upon the nerves of the opposite side. Dr Alison was present at this experiment.

Exp. XI.—The *nerves* and *constrictor muscles* of the *pharynx* were exposed on one side in a middle-sized dog, immediately after it had been killed. Pinching the *glosso-pharyngeal*, was followed by convulsive movements of the upper part of the constrictors of the pharynx, and stylo-pharyngeus muscle, but on separating a large twig of the pharyngeal branch of the *par vagum* which lay below it, and which was also embraced by the forceps, no effect followed from irritating the *glosso-pharyngeal* alone. Pinching the pharyngeal branch of the *par vagum* was followed by vigorous movements of all the *constrictors* of the *pharynx* and *stylo-pharyngeus* muscle. The same observations were repeated on the opposite side.

In two other experiments convulsive movements in the *stylo-pharyngeus* muscle and *upper part* of *pharynx*, such as was observed by Mr Mayo in the ass, followed the pinching of the *glosso-pharyngeal*; but in these the nerves had been cut through hurriedly, and when covered with blood, so that it was afterwards impossible to say whether the large ascending twig of the pharyngeal branch of the *par vagum* was included along with the glosso-pharyngeal or not. The movements observed were such as in other cases attended the irritation of that twig of the pharyngeal branch of the *par vagum*. Recalling to my recollection these facts, and

the result of Exp. XI., I determined to repeat my observation in a more accurate manner.

Exp. XII.—The nerves and pharyngeal muscles were exposed in a large Newfoundland dog, after receiving a poisonous dose of prussic acid. The glosso-pharyngeal nerve was cut across and galvanism applied, but this was so close to the communicating twig of the pharyngeal branch of the *par vagum*, that no accurate observations could be made. The nerve was then rapidly but carefully displayed on the opposite side without disturbing it, and it was observed that when it was pricked with the forceps posterior to, or on the proximal side of the point where it was joined by the communicating branch, so often mentioned, no movement resulted: on the other hand, the application of the forceps at a certain distance anterior to or on the distal side of this junction, was followed by convulsive movements of the upper part of the pharynx. On irritating the pharyngeal branch of *par vagum*, rapid and vigorous movements of all the pharyngeal muscles and upper part of the œsophagus followed.

Exp. XIII.—The difference between the effects of irritating the *glosso-pharyngeal*, anterior and posterior to the junction of the communicating branch, was also observed in this experiment performed upon a young dog. The same extensive movements of the *constrictors* of the *pharynx* and upper part of *œsophagus* were again witnessed on pricking the *pharyngeal branch* of *par vagum*. On opening the anterior part of the *pharynx*, these movements were also seen to extend to the muscles of the isthmus of the fauces and soft palate, as indicated by the motions of those parts. Irritation of the *glosso-pharyngeal* was again repeated when the *pharynx* had been opened, but still no muscular movement could be detected.

The preceding experiments appear to me sufficient to prove that the glosso-pharyngeal cannot be considered a motor nerve. I am perfectly aware that negative are infinitely less conclusive than positive experiments, and that one well-ascertained positive will outweigh a whole host of negative experiments, so that if I had been satisfied even in one of the ten experiments that muscular movements followed the irritation of the glosso-pharyngeal, when fairly insulated from the pharyngeal branch of the *par vagum*; or if these experiments did not furnish a sufficiently plausible explanation of the cause of the discrepancy between these results and those obtained by Mr Mayo upon the ass, I must have been compelled to admit that the glosso-pharyngeal was also a motor nerve, though to a limited extent. The conclusions I have formed regarding the difference in function between the glosso-pharyngeal and pharyngeal branch of the *par vagum* are also greatly supported by their ultimate distribution upon the *pha-*

rynx and *fauces*, as I shall afterwards point out when we come to the consideration of the functions of the pharyngeal branches of the *par vagum*.

With regard to the argument in favour of the motor properties of this nerve, drawn by Müller from its anatomy, it appears to me that this analogical mode of investigation, valuable though it be, must be permitted to yield to the more positive observations obtained from experiments. Of the existence of the *ganglion jugulare N. glosso-pharyngi*, which was first pointed out by Ehrenritter,* and more lately described by Müller;† and of its apparent limitation to the posterior filaments of the nerve, I am fully convinced from actual examination. And though it must be granted that this nerve here resembles very closely the double roots of the spinal nerves, yet we must be wary in drawing analogies between the glosso-pharyngeal and the spinal nerves, for we have another ganglion situated immediately below this, viz. the *ganglion petrosum* of Andersch, which involves the whole trunk of the nerve; and to this assuredly we have no analogical structure in the spinal nerves, if we admit that the superior ganglion resembles those upon their posterior roots. Müller no doubt supposes that this inferior ganglion differs from those placed upon the posterior roots of the spinal nerves, and that it belongs to the sympathetic system. But as nothing like conclusive proof is advanced in support of this opinion, we may, in the meantime, reasonably suspend our belief as to the probable influence which this lower ganglion may exert upon the functions of the nerve. ‡

Since, then, we are led to believe that the glosso-pharyngeal is entirely a nerve of sensation, and that the muscular movements which result from its irritation depend not upon any influence extending downwards along the branches of the nerve to the muscles moved, but to a reflex action exerted through the medium of the central organs of the nervous system, we have next to inquire whether or not these muscular contractions resemble any of the instinctive associated muscular movements concerned in the Function of Deglutition. It appeared to Dr Alcock that they strictly resembled the associated movements which are "ordinarily excited by a disagreeable sensation experienced in the fauces and pharynx." § There is little doubt that the muscles thus thrown into action are those concerned in regulating the course of the ingesta along the pharynx; but I have not, after

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* Tiedmann's Zeitschrift für Physiol. Vol. ii. p. 175.

† Arch. für Anat. und Physiol. 1834. p. 11.

‡ Is it possible that the filaments which do not pass through the ganglion jugulare can be connected with the specific sensations of the fauces and pharynx?

§ Op. cit. p. 264.

very frequent opportunities of carefully watching this movement, been able to satisfy myself that it resembled very closely any of the associated movements usually engaged in this function. If asked, however, to which of them it most nearly approximated, I would say, to a rapid act of deglutition, with this difference, that in the action of deglutition there is much more extensive movements of the larynx and lower part of the pharynx indicated by the ascent and subsequent descent of the hyoid bone and thyroid cartilage. I endeavoured in several of the experiments, by gently pricking, pulling, and pinching the nerve, to produce the more slow and usual effects of deglutition, or of those "excited by disagreeable sensations in the fauces and pharynx," but without success. From what I have already said it appears that the excitation of these extensive muscular movements is connected with the *pharyngeal portion* of the nerve, and under the term pharyngeal, I here include a great part of the filaments going to the fauces. I am satisfied that this phenomenon is essentially different from one of those rapid involuntary muscular movements not unfrequently produced by the sudden excitation of pain. I have watched the effects of cutting and otherwise irritating some of the superficial nerves of the cervical plexus which are exposed in displaying this nerve, and I am convinced that they cannot be classed under the same head. The muscular movements of the throat and face observed on irritating the glosso-pharyngeal were sometimes as well marked when the animal was otherwise quiescent, as when also attended by the general struggles of the animal. We believe, then, that these pharyngeal filaments possess specific endowments connected with the peculiar sensations of the mucous membrane, upon which they are distributed, though we cannot pretend to speak positively in what these consist. The apparent difference in the endowments of the *pharyngeal* and *laryngeal* branches might readily suggest some speculations upon the differences in the sensations of those portions of the mucous surface upon which they are ramified, but from these we at present abstain.

The next subject of inquiry which naturally presents itself is, what effect has section of the glosso-pharyngeal nerve upon the *functions of deglutition?* I certainly supposed, after witnessing these extensive movements of the muscles of the throat and lower parts of the face, excited by irritation of the glosso-pharyngeal, that upon this nerve must depend those sensations of the fauces and pharynx which give rise to the associated movements of deglutition. I therefore fully anticipated that section of this nerve would seriously interfere with the proper performance of these functions; and it was only after I could no longer resist the facts ascertained by my subsequent experiments, that I reluctantly abandoned the idea. The chief embarrassment experienced in

arriving at satisfactory results on this point, was the great difficulty of dividing the nerve before it had given off any of its branches. To display the trunk of the nerve became to us a comparatively easy process; but to cut it close to the *foramen lacerum*, and before it had given off any of its twigs, remained to the last a matter of great perplexity. It was only after repeated failures that we fairly succeeded in effecting this on both sides, and I was never fully satisfied that the nerves were satisfactorily divided, until I had carefully dissected the parts after the death of the animal. After we had succeeded in exposing the trunk of the nerve, and traced it back to the neighbourhood of the *foramen lacerum*, it was always necessary to proceed with great caution, as it here lies in close apposition with the trunks of the *par vagum*, spinal accessory, hypoglossal, and the sympathetic; and when to the difficulty of separating parts thus placed so closely to each other, and lying at the bottom of a deep wound, we add the obscurity so frequently arising from the blood poured out from the division of the numerous small vessels surrounding these nerves, and the frequent and violent struggles of some of the animals whenever the glosso-pharyngeal was seized by the forceps; some notion may be formed of the difficulty of succeeding in this attempt. I ascertained that several of the animals in which all the branches of the nerve had been fairly divided, except one or two of the small twigs going to the pharynx, could nevertheless swallow perfectly in from ten days to a fortnight, in other words, after the pain and swelling arising from the incisions had considerably abated. As, however, I had seen equally vigorous muscular movements excited by pinching one of the *pharyngeal twigs*, as from the trunk of the nerve itself, I considered these unsatisfactory. In three dogs, which lived long enough after the perfect section of the trunk on both sides, to enable me to make decisive observations, the power of swallowing was perfectly retained. The most satisfactory of these I shall here shortly detail.

Exp. XIV.—The glosso-pharyngeals were divided in a middle-sized young terrier. This animal recovered rapidly from the effects of the operation, and a few days after it swallowed small morsels readily. Ten days after it swallowed large masses with great facility, notwithstanding the wounds in the neck were still open. Fourteen days after the operation it was repeatedly tried with morsels of various sizes, and there could be no doubt that he swallowed large masses quite readily and as perfectly as ever he did. These observations were again repeated to the perfect satisfaction of all those present. It was then killed, and a careful dissection made of the nerves experimented on. The upper cut ends of the glosso-pharyngeal nerves were found lying within the *foramen lacerum*, and not a single filament arose from

either nerve above the point where they had been divided. More than an inch of each nerve had been removed. This last experiment, being a positive one, is alone sufficient to decide, independent of the other two which I might also detail, that the glosso-pharyngeal is not the sole nerve upon which the sensations of the fauces and pharynx necessary to the act of deglutition depend, though I believe there can be little doubt, both from its extensive distribution upon the mucous surfaces of these parts, and from the evidence afforded by the experiments upon the effects of pinching its pharyngeal branches that it must be concerned in exciting those sensations. Other nerves of sensation are distributed upon these surfaces, viz. the descending palatines of the second branch, and a few filaments from the lingual portion of the third branch of the fifth, upon the mucous membrane of the *soft palate* and *isthmus* of the *fauces;* and branches of the *laryngeal* nerves, but principally of the *superior laryngeal* upon the mucous membrane of the *pharynx*. What would be the result of cutting all these nerves, I have not yet attempted to ascertain, but having first satisfied myself that section of the *superior laryngeals* does not interfere with the act of swallowing, I performed the following experiment.

Exp. XV.—Both the *glosso-pharyngeals* and *superior laryngeal* branches of the *par vagum* were cut in a stout terrier dog. Shortly after the operation he swallowed several pretty large morsels of animal food quite readily. Next day he also swallowed two or three pretty large morsels in such a manner as to satisfy me, that if the swelling and inflammation were subdued, his powers of deglutition would not be impaired. On the third day he was seized with pneumonia, and died before any other accurate observations could be made. On dissection, these two nerves were found to be satisfactorily divided on both sides. This experiment was repeated upon another dog, but this animal died two days after, without even attempting to swallow. I, however, feel so confident, from what I saw in the first dog, that the section of both these nerves would not affect the associated movements of deglutition, that I have not thought it necessary to repeat the experiment The inference to which these experiments naturally lead us, is, that when the palatine branches of the fifth pair are uninjured, these are sufficient of themselves to furnish the sensations upon which the associated muscular movements of deglutition depend.

The results thus obtained regarding the effects of section of the glosso-pharyngeal upon the function of deglutition differ considerably from those observed by Dr Alcock, for, according to that gentleman, in those instances in which the nerve was perfectly divided " the deglutition was so much interfered with as in some cases to be impossible,"—"it (the animal) often experienced so much

difficulty as to become much exhausted, or to seem even in danger of suffocation before it succeeded." * The experiments which I have detailed above, are sufficient to show that these effects are not the necessary consequence of the perfect section of these nerves. And as the results obtained by Dr Alcock were only observed by me when the *pharyngeal* branch of the *par vagum* was divided, never when it was left uninjured ; and as I shall afterwards show, that the section of this nerve alone is sufficent to produce these effects, I am irresistibly led to conclude that this gentleman must have divided that nerve along with the glosso-pharyngeal. Indeed this might be inferred from his own words, for in criticising the experiments of Panizza, and attempting to point out the sources of error by which he supposes he must have been misled, Dr Alcock describes the glosso-pharyngeal in such a manner, as to leave no doubt in my mind, after frequent and careful dissection of the parts, that his *pharyngeal* branch of the glosso-pharyngeal is really the *pharyngeal* branch of the *par vagum*. As I have already pointed out, the relation of these two nerves to each other is so close, that it is only by frequently tracing them to their origin, that we are able to distinguish them readily in all cases.

It is unnecessary to state how much these experiments are at variance with the opinion of Sir C. Bell, that the function of this nerve is to associate the movements of the tongue and pharynx with the muscles of respiration in the instinctive movements of deglutition. It is obvious from the experiments already and to be subsequently mentioned, that these associated movements of the *tongue* must depend upon the *hypoglossal*, and those of the *pharynx* upon the *pharyngeal branch* of the *par vagum*. Mr Shaw states,† " that the powers of this nerve over the pharynx has been shown by several experiments, the results of which are very curious, and corroborative of the views (viz. of combining the movements of the tongue and pharynx) deduced from comparative anatomy." What these experiments were we are not informed ; but it must be obvious from those related above, that the derangements of these movements were not necessarily connected with lesion of this nerve. Besides, the anatomical fact, that the lingual portion of this nerve is distributed entirely, or almost entirely, to the mucous surface of the tongue, is sufficient to entitle us to call in question its alleged motor powers over that organ, if it is supposed by the supporters of this opinion to act as a motor nerve.

We have lastly to inquire in what manner the section of the glosso-pharyngeal nerve affects the Sense of Taste. My observations on this head are in perfect accordance with those of Dr Al-

* Oper. cit. 261.

† London Medical and Physical Journal, Vol. xlix. p. 453.

cock. Dr Alison had an opportunity of witnessing the persistence of the sense of taste in one of the dogs, after a portion of the trunk of the nerve on both sides had been removed, and Dr Sharpey was perfectly satisfied that the animal, the subject of Exp. VI. was sufficiently sensible of disagreeable impressions upon this sense. And though in the case witnessed by Dr Alison a few pharyngeal filaments, and in that witnessed by Dr Sharpey one pharyngeal twig on one side, were found to have been left uncut, yet it was obvious that the rejected morsel sprinkled with coloquintida was fully recognized before it passed beyond the anterior part of the mouth I need not add, that the lingual portion of the nerve was fully divided in both of these cases. The remark, however, was repeatedly made, (and it is of importance, as explaining the error of Panizza on this point,) that if animal food was offered, and the dog very hungry, he would eat the morsel containing the coloquintida rather than lose it; though he refused it if he saw any prospect of procuring another free from the bitter. The subject of Exp. I., in which, as was stated, the glosso-pharyngeal was cut on one side only, even eat readily several pieces of bread dipt in a strong infusion of gentian root. Lest any doubt may arise that the presence of a few pharyngeal branches could have influenced the sense of taste, I may adduce the subject of Exp. XIV., to prove that when the nerve is divided before it has given off a single filament, still the animal retains a sufficiently acute perception of disagreeable savours. I have fed that dog with morsels of animal food from my hand; and after he had taken several morsels in this way, which he readily swallowed, I then presented a morsel similar in size to the others, and with the coloquintida concealed in a way that he could not see it, but no sooner was it taken into the mouth, than it was rejected with evident symptoms of disgust. This was repeated more than once. I find that Müller in the second No. of his Archives for this year (1837) states that some experiments were performed in Berlin, in the summer of 1836, by a Dr Kornfeld, in which persistence of the sense of taste was ascertained after section of this nerve. It is very probable, nevertheless, that this nerve, though not the special nerve of the sense of taste, as supposed by Panizza, Dr M. Hall and Mr Broughton* may yet participate in this function, along with the lingual portion of the third branch, and the palatine twigs of the second branch of the fifth pair. This view is not only supported by the anatomical fact, that the mucous membrane and papillæ of the tongue, for about an inch in front of the *foramen cæcum*, are almost entirely supplied by this nerve, but also by the experiments of Dr Alcock† I endeavoured to ascer-

* Sixth Report of British S. Association. † Op. cit.

tain the state of the sensibility, and of the sense of taste in that portion of the tongue where this nerve is ramified, after the trunk had been divided on both sides; but from the restlessness and struggles of the animals, I was unable to arrive at any satisfactory results.

From a review of all the experiments which I have performed upon the *glosso-pharyngeal nerve*, I am inclined to draw the following conclusions:

1. That this is a nerve of *common sensation*, as indicated by the unequivocal expression of pain by the animal, when the nerve is pricked, pinched, or cut.

2. That mechanical or chemical irritation of this nerve before it has given off its pharyngeal branches, or of any of these branches individually, is followed by extensive *muscular movements* of the throat and lower part of the face.

3. That the muscular movements thus excited, depend, not upon any influence extending downwards along the branches of the nerve to the muscles moved, but upon a *reflex action*, transmitted through the central organs of the nervous system.

4. That these *pharyngeal branches of the glosso-pharyngeal* possess endowments connected with the *peculiar sensations* of the mucous membranes upon which they are distributed, though we cannot pretend to say positively in what these consist.

5. That this cannot be the sole nerve upon which all these sensations depend, since the perfect division of the trunk of the nerve on both sides does not interfere with the perfect performance of the *function of deglutition*.

6. That mechanical or chemical irritation of the nerve, immediately after the animal has been killed, is not followed by *any muscular movements*, when sufficient care has been taken to insulate it from the *pharyngeal branch of the par vagum*. And we here again observe an important difference between the movements excited by irritation of the *glosso-pharyngeal* and those of a motor nerve. For while the movements produced by the irritation of the *glosso-pharyngeal* are arrested as soon as the functions of the central organs of the nervous system have ceased, those from irritation of a motor nerve, such as the *pharyngeal branch of the par vagum*, continue for some time after this, and when all connection between it and the *medulla oblongata* has been cut off.

7. That after perfect section of the nerve on both sides, the *sense of taste* is sufficiently acute to enable the animal readily to recognize bitter substances.

8. That it probably may participate with other nerves in the performance of the function of taste, but it certainly is not the special nerve of that sense.

Lastly, the *sensation of thirst*, which is referred to the *fauces* and *pharynx*, does not appear to depend entirely upon the presence of this nerve. The animals in which it was divided lapped water of their own accord. I observed one of them in which the nerves were found satisfactorily divided, rise, though very feeble, walk up to a dish containing water, lap some of it, and return again to the straw upon which he was previously lying.

To Dr J. Duncan and Mr J. Spence, I am most deeply indebted for their valuable assistance in the performance of these experiments upon the glosso-pharyngeal nerve and the greater part of those which are to follow. It is obvious, that without the aid of active and intelligent assistants, it would have been perfectly impossible to have proceeded with such an investigation. These two gentlemen witnessed the facts stated in the preceding experiments, and I have their sanction for their accuracy.

Part II.—*Pneumogastric Nerve.*

I shall first consider the immediate effects of the mechanical and chemical irritation of that part of the trunk of this nerve which lies in the neck, and then proceed to the separate investigation of the functions of its *pharyngeal*, *laryngeal*, *œsophageal*, *cardiac*, *gastric*, and *pulmonary* branches.

I have exposed the trunk of the *par vagum* in the neck in at least thirty animals, and in almost all of these, the pinching, cutting, and even the stretching of the nerve were attended by *indications of severe suffering*. It was frequently difficult to separate the nerve from the artery, on account of the violent struggles of the animal, though some of them had been pretty quiet during the previous part of the operation. It has appeared to me, however, that a considerable degree of stretching and even compression may in many cases be exercised, without exciting any apparent suffering, when these are gradually applied. And this may perhaps account for the statement of Dr M. Hall and Mr Broughton,* that "in pinching the *par vagum* neither of the phenomena above-mentioned (viz. sensibility and muscular movements) occurs." Very few of the numerous experimenters upon the *par vagum* say any thing about the sensibility of this nerve, apparently, because their investigations were almost always conducted with a view to ascertain the effects of its section upon the circulatory, respiratory, and digestive functions. I find, however, that Haller, in some experiments expressly undertaken for the purpose of ascertaining the degree of sensibility possessed by the nervous trunks, observed unequivocal signs of suffering on injuring the pneumogastric nerves. In relating an experiment upon

* Reports of British S. Association, Vol. iv. p. 677.

a rabbit, he says, " Utcunque nervorum octavi paris, resecuimus, miseris cum doloribus, et contorsionibus animalculi." * Again, in describing the effects of the application of a ligature upon these nerves in another rabbit, it is mentioned, " ejulavit inter vinciendum miserum animal." † Brunn, in detailing several experiments upon the effects of including the *par vagum* in a ligature, describes the animals as giving undoubted evidence of feeling pain. ‡ Dupuy states, in giving the details of one of his experiments, that " l'animal témoigna beaucoup de douleur pendant la division du nerf. § Dumas also, in relating an experiment upon this nerve, informs us, that when " on passe ensuite une ligature autour du nerf pneumogastrique ; il témoigna par ses mouvements et par ses cries la vivacité de sa douleur." ‖ It is stated by Dr M. Hall and Mr Broughton, ¶ that when the compression of this nerve is continued " for a few moments, an act of *respiration and of deglutition follows, with a tendency to struggle and cough.*" I have frequently repeated this experiment ; and though in some of the animals powerful respiratory movements were produced by compressing the nerve, which were soon followed by struggles, yet I have never observed either any tendency to cough or any act of deglutition, which I could fairly refer to this cause. The most satisfactory of these experiments I may here shortly relate.

Exp. XVI. The pneumogastric nerves were exposed in a middle-sized mongrel dog. On laying hold of the nerve with the forceps, rather gently at first, but soon increasing the pressure so as to squeeze it pretty firmly, no effect was observed for a few seconds, but the breathing then became somewhat heaving, with a noise resembling snoring. This was repeated twice on each nerve, and always with the very same effects. The struggles attending the compression of the nerve in this animal were very slight.

Bichat contends that the increased respiratory movements accompanying the irritation of the *par vagum* depend solely upon the sudden excitation of pain. ** Unquestionably the sudden infliction of pain hurries the respiration ; but I believe that there can be no doubt that Bichat was in error, when, to this circumstance alone he attributed all the increased respiratory movements observed on irritating the pneumogastric nerves. In case it may be argued that these increased respiratory efforts arise from the partial ar-

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* Opera Minora, Tom i. p, 360. Exp. 136. Laus. 1762.
† Oper. cit. Tom i. p. 359. Exp. 132.
‡ De Ligaturis Nervorum, Ludwig, Tom ii. Scrip. Nov. Min. Sel, p 285-6-7.
§ Journal de Medecine, Chirurg. &c. Dec. 1816. p. 359. Exp. iv.
‖ Journal Général de Médecine, Tome xxxiii. p. 356.
¶ Oper. cit. 677.
** Sur la Vie et la Mort, p. 316, 2d ed.

restment of the movements of the glottis consequent upon compression of one of these nerves, I may state that I have seen them in two cases when the animal was breathing through a large opening in the trachea. That these increased respiratory movements are not dependent upon any direct effect which irritation of this nerve has upon the lungs or thoracic muscles, is proved by the fact, that when the nerve is cut across, the irritation of the portion in connection with the *medulla oblongata* alone excites these movements.

Before proceeding to the consideration of the function of the pharyngeal branches of the *par vagum*, I may here briefly advert to the effects of section of the *par vagum* upon the conjunctival membrane of the eye, when practised upon those animals in which the sympathetic is so closely connected to this nerve, that the one cannot be divided without the other. I had several opportunities of witnessing these on dogs. At a longer or shorter period, after the trunks of the *par vagum* and the accompanying sympathetic nerves were divided, the conjunctiva became red, swollen, and projected over the cornea. The pupil was contracted, and only a small part of the ball of the eye was seen between the half-closed eyelids. This inflammation frequently went on to the secretion of purulent matter, and after lasting some time began gradually to abate. Petit was the first who observed these effects upon the eye after the section of the *par vagum*, and justly attributed them to the division of the trunk of the sympathetic; for he was perfectly aware of the connection of this nerve with the sixth pair and first branch of the fifth pair within the cavernous sinus, and of the intimate relation of the trunk of this nerve with that of the *par vagum* in the neck in quadrupeds. * Cruickshank also noticed this inflammation of the conjunctiva in his experiments upon the *par vagum*. In the first of these it is mentioned that there was "heaviness and slight inflammation of the eye," and in Exp. II., III., and IV., "the eyes," we are told, "became instantly red and heavy." †

That Petit was right in supposing this inflammation of the eye to arise from section of the sympathetic and not of the *par vagum*, has been fully demonstrated by the experiments of Dupuy,‡ upon the effects of the removal of the superior cervical ganglion of the sympathetic. These experiments have been more lately confirmed by Brachet.§ This inflammation of the eye frequently takes place with great rapidity after section of the sympathetic. In one case,

* Memoire dans lequel il est demontré que les Nerfs Intercostaux fournissent des rameaux, qui se portent les esprits dans les Yeux; dans l'Histoire de l'Academie Royale des Sciences, Année 1727.

† Philos. Transact. 1795, Part 1st, or Medical Tracts and Observations, Vol. vii. p. 136.

‡ Journal de Médecine, Chirurgie, &c. December 1816, Tome xxxvii. p. 340.

§ Fonctions du Système Nerveux Ganglionaire, Chap. ix. 1830.

I observed the conjunctiva reddened a very few minutes after the operation. In two of Petit's experiments, it is mentioned that in a quarter of an hour after the section of the nerves, the cartilaginous membrane, at the inferior angle of the eye, had encroached upon the cornea. In the fourth experiment by Dupuy upon the horse it is stated, "Aussitôt apres l'opération," the eyelids were swelled, and the eyes watery. This inflammation appears to be confined to the conjunctiva,—the contracted pupil and half-closed eyelids probably depending upon the impatience of light generally accompanying this condition. Petit mentions that he killed a dog on the third day after the operation, and on dissection found the inflammation apparently restricted to the conjunctiva. We do not, however, consider it fairly ascertained that the inflammation is confined merely to the surface of the eye. In the experiments of Dupuy and Brachet upon the effects of the removal of the superior ganglion of the sympathetic, to which I have referred, the same phenomena presented themselves, as far as the eye was concerned, as when the *par vagum* is cut in the neck. This inflammation of the conjunctiva from section of the sympathetic in the neck, cannot in all probability be referred to the same cause as that arising from section or disease of the fifth pair; the former occurring almost instantaneously, without arrestment of the usual secretion, and apparently from some direct effect upon the blood-vessels or their contents; the latter coming on more slowly, and apparently arising, as has been ingeniously suggested, from the arrestments of the usual secretions which protect the conjunctiva from the irritating effects of the external atmosphere, as seen in various cases when the nerves of secreting surfaces are cut.*

Pharyngeal branches of par vagum.—In the human species we not unfrequently find two pharyngeal branches of the *par vagum*, the lower and smaller of which, as Wrisberg describes, is composed of a filament of the *par vagum*, conjoined with others from the sympathetic. In the dog, (upon which the following experiments were made,) there is only one pharyngeal branch of the *par vagum* on each side as far as I have observed, and this is composed, as in the human species, of a twig from the internal branch of the spinal accessory, united with another twig from the *par vagum*.

These branches of the *par vagum* have not, as far as I am aware, been previously made the subject of experimental investigation, so that their exact functions have hitherto only been a matter of conjecture.

Is the pharyngeal branch of the *par vagum* both a *motor* and *sensitive* nerve? We have adduced sufficient evidence when

* Alison's Outlines of Physiology, p. 148.

detailing the experiments upon the glosso-pharyngeal, to prove that this is a motor nerve, for in repeated experiments made upon animals immediately after death, its mechanical and chemical irritation produced distinct convulsive movements of the muscles in which it is ramified. It is also there stated that the movements seen on irritating this nerve immediately after death are generally very vigorous, and embrace not only the *constrictors* of the pharynx and *stylo-pharyngeus*, but also the muscles of the soft palate. These facts are of themselves sufficient to entitle us to conclude that this is a motor nerve of these muscles; and if we are correct in inferring that the glosso-pharyngeal is entirely a nerve of sensation, we may proceed still farther in our inductions, and affirm that this is the principal, if not the sole motor nerve of these parts. * In experimenting upon this nerve in the living animal, it is best exposed in the manner described for displaying the glosso-pharyngeal. I find that I have notes of observations made upon the effects of pricking, cutting, and tying these nerves in seven dogs. In four of these it is expressly stated that there were not the slightest indications of suffering; in two, that there were no decided indications of suffering; and that in one, there was undoubted evidence of suffering, when these nerves were irritated in the manner mentioned. In all the seven animals, with the exception of the last, the difference between the results of pinching this nerve and the glosso-pharyngeal were very marked. It is quite possible that if this animal, instead of being kept alive for further observation, had been killed at the time, and the nerves carefully dissected, some unusual arrangements of the nervous twigs might have accounted for this difference; for in the other six the nerves were as I have stated, pricked, cut, and tied, and yet no decided evidence of the excitation of pain showed itself. I also distinctly remember, though I have made no mention of it in my notes taken at the time, that we pricked the trunk of this nerve, or its large descending branch in some cases, where these were exposed in experimenting on the glosso-pharyngeal, without causing pain. When we add to all this the smallness of the nerve, compared with the extent of the muscles moved by it, we are led to believe that the sensitive filaments contained in this nerve must be very few, if, under ordinary circumstances, there are any present at all. I may state, that, in one of the animals, in which the constrictors of the pharynx were more freely exposed than usual in operating on the living animal,

* It is perhaps going too far to say, that it is the sole motor nerve of these parts; for Paletta, in describing the smaller portion of the fifth pair, states, that a twig from the external pterygoid branch passes to the *circumflexus palati* muscle. Ludwig. Scrip. Nov. Min. Sc. Tom iii. p. 71. Mayo also mentions this twig (No. ii. Anat. and Physiol. Comment.)

vigorous contractions were observed in these muscles, when the nerve was pricked with the forceps. I need not state, that to insure accuracy in such experiments, care must be taken that they be made upon the pharyngeal branch of the *par vagum*, before it has received any communicating filament (if such be present) from the glosso-pharyngeal, and that the descending filaments of the glosso-pharyngeal, which cross this nerve, be excluded.

Effects of section of the pharyngeal branch of the par vagum upon the function of deglutition.—If this nerve be, as we have supposed, the motor nerve of the muscles of the pharynx and isthmus of the fauces, the section of it ought to be followed by considerable derangement of this function. To test this opinion, the pharyngeal branch of the *par vagum* was cut across on both sides, and a portion of it removed, in five dogs. On three of these, satisfactory observations were made. In all the three, the function of deglutition was considerably impaired, and this was manifested exactly in the same manner. I shall only briefly detail one of these experiments.

Exp. XVII.—The *pharyngeal branch* of the *par vagum* was cut on both sides before it had given off any branches. The inflammation and swelling of the neck were allowed to subside before any observations were noted down. This animal, on swallowing a morsel of moderate size, could convey it readily into the posterior part of the mouth; but at this stage of the process of deglutition it began to make strong movements of the muscles of the neck; during each of these the head was carried down towards the thorax. After a greater or less number of these efforts, the animal again looked out for a fresh portion of food. When the morsel was very small, one or two of these movements were generally sufficient to pass it through the *pharynx*; if large, the movements became more violent, numerous, and prolonged.

It appears, then, that when these *pharyngeal* branches of the *par vagum* are divided, and the *pharyngeal* and *palatine muscles* paralysed, the food is forced through the pharynx to the commencement of the œsophagus, by the powerful contraction of the muscles of the tongue, and those attached to the larynx and hyoid bone, all of which are moved, except the *digastric* and *stylo-hyoid* muscles, by the *hypoglossal* and descending branches of the *cervical plexus* of nerves. When the morsel is small, the movements of these muscles seem to force it pretty readily (as can be easily imagined) through the bag of the *pharynx*, to the upper part of the *œsophagus*, when drawn forwards and dilated by the ascent of the *hyoid bone*. The difficulty must obviously increase as the size of the morsel increases; and the most violent efforts of the muscles which move the *hyoid* bone

and *larynx* are necessary, if they succeed at all, in forcing a large mass through the *pharynx*.

While, then, the glosso-pharyngeal is one of the nerves upon which the sensations of the pharynx and fauces depend, the pharyngeal nerve of the *par vagum* is a motor nerve of the same parts. This view of the functions of these nerves is supported by their ultimate distribution upon the pharynx and fauces, as far as I have been able to trace it. From the free anastomoses of the filaments of the glosso-pharyngeal, pharyngeal branches of the *par vagum*, and the sympathetic, forming what is properly called the *pharyngeal plexus*, it is absolutely impossible to trace all, or even the greater part of these filaments to their ultimate distribution, unmixed with each other. But, from several minute dissections of these nerves on the human subject, and also upon the dog, where the ramifications of these nerves are fewer and larger, and do not appear to anastomose so frequently as in the human species, I have satisfied myself that those filaments of the pharyngeal branch of the *par vagum*, which do not anastomose with others from the glosso-pharyngeal, are entirely ramified in the muscular fibre; while on tracing the unmixed filaments of the glosso-pharyngeal, they generally, after a long and winding course through the muscular fibres, pass ultimately to the mucous membrane, so that comparatively very few of these are lost in the muscular fibres.

That a few of the filaments of the glosso-pharyngeal appear to be lost in the muscular fibre, is certainly no proof that this is partly a motor nerve; for as it has been shown by Sir C. Bell, and the fact is easily verified, the muscular fibres belonging to the animal functions (and the palatine and pharyngeal muscles are as it were on the debatable ground between the animal and organic functions,) are supplied with sensitive as well as with motor filaments, to endow them with the muscular sense. If these attempts to unravel the functions of the most important of the complicated nerves of the pharynx and fauces, and to ascertain their relative shares in the performance of the function of deglutition, be still imperfect, I may be excused on account of the intricacy of the subject, and particularly when it has been stated on the best authority, that, up to this period, "the precise office of each nerve in these parts has not been ascertained." *

Laryngeal Branches of Par Vagum.—Before proceeding to the consideration of the experiments upon the laryngeal branches of the *par vagum*, we shall advert for a little to their anatomical distribution upon the larynx, since this bears in a direct manner upon some of the most important questions connected with the functions of these nerves.

* Alison's Outlines of Physiology, p. 213.

After it had been demonstrated by the experiments of Legallois, that compression or section of the *inferior laryngeal nerves*, or of the trunks of the *pneumogastrics*, above the origin of these branches, arrested the movements of the muscles of the *glottis*, and were frequently followed by dyspnœa, and even by suffocation, particularly in young animals; and when it had also been ascertained by the observations of physicians, that derangement of the movements of these muscles is also not unfrequently the cause of alarming paroxysms of *dyspnœa*, more especially in children, occasionally terminating in death, it became an object of considerable practical importance to ascertain the relative share which these nerves have in regulating the movements by which the aperture of the *glottis* is diminished or enlarged. For without a correct knowledge of the manner in which these movements are produced in the healthy state, it is apparent, that we cannot with safety advance one step in the explanation of their deranged conditions.

There are obviously two methods of examining this question, viz. by tracing these nerves to their ultimate distribution, and by experiments on animals. If in following the first method, we find that one of these nerves is distributed upon certain muscles of the *larynx*, and not upon others, we must of course consider it as finally ascertained that this nerve has no effect, in regulating, as a motor nerve, the movements of those muscles, upon which it is not distributed. And, as is well known, the anatomical arrangement of these nerves is the strongest fact adduced by Magendie in favour of his opinion, that the *superior laryngeals* move the muscles which shut the superior aperture of the *glottis*, and the *inferior laryngeals* or *recurrents* those which open it. For according to Magendie, * Cloquet,† and many other anatomists and physiologists who have taken it on their authority, the *arytenoid muscles* receive their nervous filaments solely from the *superior laryngeals*. That filaments of the *superior laryngeal nerves* pass into the *arytenoid muscles* is allowed by all anatomists; but there can be as little doubt that they receive a filament from each of the *inferior laryngeals*. Among those who have described this *arytenoid* branch of the *inferior laryngeal or recurrent*, previous to the announcement of this statement by Magendie, we may mention Andersch,‡ Bichat, § and J. F. Meckel. ‖ And, among those who have since that time examined these nerves, and ascertained the existence of this *arytenoid* branch, we may mention Rudolphi, ¶

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* Compendium of Physiology, 4th edit. p. 132. Milligan's Translation.

† Traité d'Anatomie Descriptive, Tome ii. p. 622.

‡ Fragmentum Descr. Nerv. Card. &c. in Tom. ii. p. 139, Ludwig. Scrip. Nerv. Min. Sel.

§ Traité D'Anatomie Descriptive, Tome iii. p. 216.

‖ Manuel D'Anatomie Gen. Descrip., &c. Tome iii. p. 66.

¶ Physiologie, Bd. ii. p. 374. These dissections were made by Schlemm.

Bischoff, * Swan, † and Cruveilhier. ‡ I have repeatedly satisfied myself of the existence of this *arytenoid* branch of the *inferior laryngeal*, and the dissection is one which can leave no kind of doubt on the matter. It is obvious that those who have failed in detecting this branch have been misled by the circumstance, that it appears to enter the *crico-arytenoideus posticus*, and to be destined for that muscle. On being traced upwards, however, it is found to continue its course inwards and upwards, between the anterior surface of the *crico-arytenoideus posticus*, and the posterior surface of the *cricoid cartilage*, to reach the lower margin of the *arytenoid muscles*. I shall shortly state the conclusions I have come to regarding the ultimate distribution of these nerves upon the *larynx* and upper part of the *trachea*, drawn from careful dissections in the human subject. The *recurrent* in its course upwards to the *larynx* sends various filaments to the muscular fibres which complete the tube of the trachea behind, and others which perforate the narrow intervals between the *cartilages* to reach the mucous membrane of the *trachea*. Having arrived at the *larynx*, it sends distinct branches to the *crico-arytenoideus posticus*, *crico-arytenoideus lateralis*, *thyro-arytenoideus* and *arytenoid muscles*, or, in other words, to all the muscles which move the arytenoid cartilages.§ These branches evidently terminate in the muscular fibre. In fact, the only filaments of the *inferior laryngeal* which appear to proceed to the mucous surface of the *larynx*, are a few from the terminating or *thyro-arytenoid branch*. I have seen one or two very slender filaments pass to the *crico-thyroid*, from that branch of the *inferior laryngeal*, which, after sending ramifications to the mucous surface of the lower part of the *pharynx*, anastomoses with the *external laryngeal* branch of the *superior laryngeal*, but these filaments do not appear to be constant.

Superior Laryngeal Nerve.—The *external laryngeal* branch of the *superior laryngeal* nerve, gives a few filaments to the *inferior constrictor of the pharynx*, more to the *thyro-hyoid muscle*, and a comparatively large and distinct branch to the *crico-thyroid*, which evidently terminates in that muscle. The internal laryngeal branch of the same nerve is almost entirely distributed upon the mucous surface of the *epiglottis* and interior of the *larynx*. By far the greater part of the filaments of this branch of the nerve which ramify in the *arytenoid*, *thyro-arytenoid*, and *crico-aryte-*

* Comment. De Nervi Accessorii Willisii Anat. et Physiol. p. 27. 1832.

† A Demonstration of the Nerves of the Human Body. Plate xvi. fig. vii. This contains a very accurate representation of the course of this twig.

‡ Anatomie Descriptive, Tome iv. p. 963. 1835. Dr Sharpey informs me that he has been accustomed to describe this branch in his lectures.

§ I here consider the muscular fibres described as the *thyro-epiglottideus* as a part of the *thyro-arytenoideus*.

noideus lateralis muscles proceed to the mucous surface, and generally after a long and winding course among the muscular fibres. They thus present a striking contrast to the abrupt manner in which the filaments of the crico-thyroid twig of the external laryngeal terminate in the muscular fibre. In fact, the only filaments of this *internal branch* of the *superior laryngeal* which appear to terminate in the muscular fibre, are some of those which pass into the *arytenoid muscles.* Those filaments which seem to terminate in the arytenoid are part of a twig which anastomoses with the arytenoid branch of the inferior laryngeal in the substance of the arytenoid muscle. A knowledge of the distribution of these nerves is, however, of itself insufficient to clear up their functions in a satisfactory manner, for it must be obvious that, though by anatomical investigation, we may ascertain that certain nerves supply particular muscles, and in this manner frequently form a pretty accurate notion of their function, yet when nervous filaments come from more than one source, and from a complex nerve like the *par vagum*, it is only by experiments upon animals, or by the observation of disease, that we can hope to ascertain which are motor, and which are sensitive. Besides the free anastomoses between those nerves must render it doubtful from which of them some of the minute filaments come. *

In entering upon the physiological investigation of the functions of the *laryngeal nerves*, I first proceeded to examine what effect the irritation of these has upon the muscles of the *larynx* in a recently killed animal.

Exp. XVIII.—The *larynx* was exposed and the *glottis* brought into view in a dog, immediately after it had been killed by a dose of prussic acid. On applying the galvanic wires to each recurrent nerve alternately, violent movements of the muscles of the *larynx* followed, and the *arytenoid cartilages* were first seen to approach each other, and then to recede. At each movement the small cartilages at the summit of the *arytenoids* (cornicula laryngis) came into close contact. On galvanising the *superior laryngeal* nerves, or rather the *internal branches* of these, for they had been cut across a little above where they perforate the *thryo-hyoid ligament*, no movement was observed. On again applying the wires to the recurrents, or to the trunk of the *par vagum* above the origin of the *recurrent*, the same results were obtained as before. The movements which followed irritation of the trunk of the *par vagum* were not so strong as those from irritation of the *recurrent* itself. Dr Alison was present at this experiment.

Exp. XIX.—The *larynx* was exposed, as in the preceding

* For some further remarks upon the anatomy of these laryngeal nerves, see Part III.

experiment, in a dog bled to death from the femoral arteries, but without dividing the *superior laryngeal nerves*. On applying the galvanic wires to the *superior laryngeals* before they had given off the *external laryngeal* branch, strong convulsive movements of the *crico-thyroid* muscle followed, by which the *cricoid* cartilage was approximated to and drawn under the *thyroid* and the *larynx* shortened. All the muscles attached to the *arytenoid* cartilages remained perfectly quiescent, so that no change took place upon the superior aperture of the *glottis*. On applying the wires to the *recurrent* nerves alternately, the same vigorous movements of the *arytenoid* cartilages were observed as in the preceding experiment. It was remarked that when the galvanic wires were kept applied to one of these *recurrent* nerves for some short time, the *arytenoid* cartilages were so approximated as to shut completely the superior aperture of the glottis. On removing one of the wires the cartilages then separated.

These experiments were repeated on five other animals with the same results. In two of these, the movements observed on irritating the nerves were much feebler than those described, but, though varying in degree, as might be expected, they never varied in kind. I may add, that these movements are also well marked when the nerves are pinched with the forceps, and after they have been detached from the trunk of the *par vagum*. In these experiments it was distinctly observed, that the only outward movements of the *arytenoid* cartilages, seen on irritating the *recurrents*, were merely occasioned by their return to their former position after they had been carried inwards. This outward movement, then, no doubt, entirely depended upon the elasticity of the parts.*

From these experiments it was concluded that all the muscles which move the *arytenoid* cartilages receive their motor filaments from the *inferior laryngeal* or *recurrent* nerves. And as the force of the muscles which shut the glottis preponderates over that of those which dilate it, so the arytenoid cartilages are carried inwards when all the filaments of one or both of these nerves are irritated. These experiments also show us, that one only of the intrinsic muscles of the larynx receives its motor filaments from the superior laryngeal, viz. *the crico-thyroid* muscle, and that, consequently, the only change which this nerve can produce on the *larynx*, as a motor nerve, is that of approximating the cricoid to the thyroid cartilage,—in other words, of shortening the larynx.

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* In these experiments I never could perceive any contractions of the *thyro-hyoid* muscle and *inferior constrictor* of the pharynx, on irritating the superior laryngeal, even when the *crico-thyroid* was acting most vigorously. Neither could I ever observe any movements of the *crico-thyroid* on irritating the recurrent. The *thyro-hyoid* muscle receives its motor filaments from the *hypoglossal* and the *inferior constrictor* of the *pharynx* from the *pharyngeal branch* of the *par vagum*.

I find that Bischoff* had examined the effect of irritating these nerves in the recently killed animal. And though he failed to observe the contractions of the *crico-thyroid* muscle, and the consequent shortening of the *larynx*, produced by irritation of the *superior laryngeal* nerve, and in place of this describes some supposed palpitation of the mucous membrane of the *larynx*, yet the other results obtained by him were similar to those we have described in Exp. XIX.

We have now to see how far the views we have stated above, are supported by the subsequent experiments on living animals.

The *superior laryngeal* nerve was cut on both sides in two dogs and one rabbit, and the animals readily swallowed both solids and fluids without exciting the slightest cough or the least difficulty of breathing. The lungs were carefully examined after death, and none of the food taken could be detected in the air-passages. In several animals the superior laryngeals were first cut, and the inferior laryngeals immediately afterwards, and it was ascertained that the previous division of the *superior laryngeals* did not prevent the difficult breathing and symptoms of suffocation, which not unfrequently follow the division of the *inferior laryngeal* nerves, particularly in young animals. To procure still more positive assurance of the effect of section of the different *laryngeal* nerves upon the movements of the muscles attached to the *arytenoid* cartilages, the following experiments were performed.

Exp. XX. All the *four laryngeal* nerves were exposed in a full-grown cat. The larynx was then dissected out by cutting between the hyoid bone, and thyroid cartilage, and drawn forwards so as to expose the glottis without disturbing the nerves. When the glottis came into view, the *arytenoid* cartilages were observed to be drawn backwards and outwards during inspiration, and to approximate considerably during expiration. The extent of these movements of the muscles of the glottis was in proportion to the extent of the other respiratory movements. When the animal was quiet and breathing less forcibly, the movements were slight. While uttering a cry, the sides of the superior aperture of the glottis were closely approximated, and were thrown into vibratory motion. While struggling violently, the superior aperture of the glottis appeared completely closed. A small opening was made into the trachea, and a silver probe passed upwards. This appeared to excite little if any uneasiness, until it arrived at the larynx. As soon as it entered the larynx it was instantly followed by close approximation of the sides of the superior aperture of the glottis, violent cough, and evident uneasiness. The same ef-

* Oper. cit. p. 27.

fect was produced by introducing the probe from above. After satisfying myself of these facts, one of the *recurrent* nerves was first cut across, with the effect of evidently diminishing the movements of the *arytenoid* cartilage on the side cut. The other *recurrent* was then divided, and instantly all the movements of the muscles of the *glottis* ceased, and the *arytenoid* cartilages were never carried outwards beyond the position in which they are found after death. The *superior laryngeals* were then cut, without effecting the slightest enlargement or any other change upon the *glottis*. As the *arytenoid* cartilages, after section of the *inferior laryngeal* nerves were now mechanically carried inwards by the rushing of the air through the diminished aperture of the *glottis*, during each violent inspiration of the animal, by which the aperture was still further contracted, its edges were kept apart with the forceps, until an opening was made in the *trachea* to prevent the immediate suffocation of the animal.* The experiment being now completed, the animal was killed by a dose of prussic acid.

Exp. XXI. The *larynx* was brought into view in another full-grown cat, as in the preceding experiment, and the various movements of the muscles of the *glottis* again watched for a short time. The *superior laryngeal* nerves were then cut without diminishing in the least any of the movements of the *arytenoid* cartilages. The sides of the superior aperture of the *glottis* were approximated in crying, so as to form but a narrow fissure, and in struggling, the aperture became completely closed, as when the *superior laryngeal* nerves were uninjured.

Nothing could be more satisfactory than the results of these two last experiments, and they complete the accumulated facts which we have adduced, in fully disproving the statement of Magendie, to which we have already referred, viz. that the *inferior laryngeal* supplies those muscles only which enlarge the aperture of the *glottis*, while the *superior laryngeal* furnishes the motor filaments to those muscles which shut the *glottis*.† They also il-

* It is important to remark, that section of the superior laryngeals did not arrest these inward movements of the arytenoid cartilages.

† Allowing even that the recurrent nerves gave no filaments to the arytenoid muscles, the proposition of Magendie, that the superior laryngeal nerve alone moves those muscles which shut the glottis, would not necessarily be correct. For it is universally admitted, that filaments of the recurrent nerve are distributed in the thyro-arytenoid muscle, and no attempt has been made to prove these filaments to be merely sensitive; on the other hand, we have seen, from the anatomical distribution of these nerves, that this muscle must receive its motor filaments from the recurrent. Now, an examination of the course of the fibres of this muscle will, we think, fully bear out the generally received notion of its action, viz. that it must assist in diminishing the aperture of the glottis. The authority of Hoffman, (Aeroteria, p. 91, as quoted by Haller,) and of Haller himself, (Element. Physiol. Tom. iii. p. 387, Laus. 1761,) may doubtless be adduced in support of the opinion, that it

lustrate in a very satisfactory manner the cause of the *dyspnœa* in some cases where the *inferior laryngeal* nerves are cut, compressed, or irritated. To the consideration of this last point we shall afterwards return. The movements of the muscular fibres of the *trachea*, no doubt, depend upon the *recurrent*, but we had no opportunity of actually witnessing this. If it were thought necessary to adduce any additional evidence, that the muscles of the glottis can act involuntarily, like the other muscles of respiration, we might state that we have seen these movements going on in unison with those of the other respiratory muscles, in animals deprived of all volition by a fatal dose of prussic acid.

We have now to examine *to what extent these nerves are connected* with sensation. And, first, with regard to the effect of irritating the trunks of these nerves. I have exposed the *superior laryngeal* nerves repeatedly in living animals, and in all, as I have already stated, decided indications of suffering presented themselves, except in two dogs which had previously endured protracted pain. In some of these dogs, distinct convulsive movements of the muscles of the throat and lower part of the face were observed, similar to, but less strongly marked than those accompanying irritation of the glosso-pharyngeal. Whether this movement depended upon the sudden excitation of pain, or of some specific sensation, similar to, though feebler than that which we suppose to attend irritation of the *glosso-pharyngeal* nerve, we cannot pretend to determine. In support, however, of this last supposition, we may urge the anatomical fact, that a considerable number of the filaments of this nerve are distributed upon the mucous surface of the *pharynx*. I was anxious to ascertain whether irritation of these nerves would produce closure of the glottis by a reflex action. As the experiment is one in which it is difficult to arrive at accurate conclusions, without inflicting much pain, I did not persevere in the attempt. I may state, however, that in Exp. XXI. we observed, that when each of the superior laryngeal nerves was cut, the glottis was suddenly closed; but whether this was occasioned by a struggle of the animal from the excitation of pain, or depended upon the muscles of the glottis being thrown

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enlarges the glottis. We consider, however, this view of the action of the muscle untenable. In confirmation of the opinion, that the action of this muscle has a contrary effect, and assists in diminishing the glottis, we may quote the authority of Cowper, Albinus, Soemmerring (Corporis Hum. Fabrica, Tom. ii. p. 138, 1794;) Meckel (Oper. cit. Tom. iii. p. 497.) and Lauth (Mem. de l'Acad. Roy. de Medec. Tom. iv. p. 110. 1835.) Some authors, as Meckel, Lauth, and Cruveilhier (Oper. cit. Tom. ii. p. 669,) even maintain that the action of the crico-arytenoidei laterales muscles, is to diminish the aperture of the glottis. Bichat also asserts, (Anat. Descrip. Tom. ii. p. 407.) that "les crico-aryténöidiens postérieurs sont les seuls agens de la dilatation de la glotte." The action of these crico-arytenoidei laterales muscles is certainly difficult to determine, as it must depend in a great measure upon the position of the *arytenoid* cartilages at the time they are thrown into action, and the synchronous contraction of other muscles.

into contraction by a reflex action, I cannot venture to decide. Irritation of the recurrent nerves is attended by much feebler indications of suffering. That this nerve does, however, contain some sensitive filaments, is indicated not only by the circumstance, that when pinched or tied, the animal generally gives symptoms of feeling pain, but also from the fact, that it sends numerous filaments to the mucous surface of the *trachea*, a few to the mucous surface of the lower part of the pharynx, and even a few to the inner surface of the *larynx*. * With regard to the effects of section of these nerves upon the sensibility of the mucous surface of the larynx, we have obtained very satisfactory results. We might *a priori* determine from the anatomical distribution of these nerves, that the sensations referred to the larynx are almost entirely dependent upon the superior laryngeal nerves. In Exp. XX. we observed that irritation of the mucous surface of the *larynx* after section of the *inferior laryngeals*, was still followed by great uneasiness and efforts to cough, while the movements of all the muscles of the *glottis* were arrested. In Exp. XXI. on the other hand, no uneasiness, or efforts to cough were excited even by rubbing the probe against the inner surface of the larynx, after section of the superior laryngeals, while the sympathetic and voluntary movements of the muscles of the glottis went on as before. I have also had occasion, while performing other experiments, to verify the same facts in the manner followed by Magendie in one of his lectures at the Collége de France.† Through an opening made into the trachea, a probe was passed upwards to the larynx. This excited little or no uneasiness until it reached the larynx. As soon as it entered the larynx, it excited great uneasiness and violent paroxysms of coughing. Section of the recurrents had no effect in diminishing the severity of these paroxysms of coughing, while they were instantly arrested by cutting across the superior laryngeals. Whether this striking difference between the sensibility of the parts supplied by the two laryngeal nerves depends upon the number of these filaments, and the manner in which they are distributed, or upon some difference in their endowments, I cannot pretend to decide.

In Exp. XX. we observed that when the *superior laryngeals* were divided, the presence of the probe in the interior of the larynx was not only unattended by uneasiness and cough, but it also no longer occasioned any sudden closure of the superior aperture of the *glottis;* and in Exp. XXI. though each introduction of the probe occasioned great uneasiness and efforts to cough after section of the *recurrents*, still the muscles of the *glottis* were not

* We shall afterwards have occasion to examine the functions of the œsophageal filaments of the recurrent.

† Lancet, July 1, 1837.

thrown into spasmodic contractions, as when they were entire. From these experiments we perceive, that when either the *recurrents* or *superior laryngeals* are divided, so as to break the nervous circle which these form through their connection with the central organs of the nervous system, irritation of the mucous surface of the *larynx* no longer excites contraction of the surrounding muscles, though their contractility has not been impaired. This nervous circle we may suppose to begin at the mucous surface of the *larynx*, to pass upwards through the filaments of the *superior laryngeals* to the *medulla oblongata*, and back again to the muscles through the filaments of the *recurrent*. I have also repeatedly attempted, but in vain, to excite contractions of the muscles of the *glottis*, by irritating the mucous surface in an animal recently killed. From these facts, we think that we are justified in concluding, that when any irritation is applied to the inner surface of the *larynx* in the healthy state of the parts, this does not excite the contraction of the muscles attached to the *arytenoid* cartilages by acting directly upon them through the mucous membrane, but that this contraction takes place by a reflex action, in the performance of which the *superior laryngeal* is the *sensitive*, and the *inferior laryngeal* is the *motor nerve*. And when we remember that no appreciable interval of time intervenes, between the application of an irritant to the mucous surface of the glottis and the contraction of its closing muscles, and reflect upon the circuitous course through which the nervous influence must travel, before it reaches these muscles to stimulate them to contraction, we may form some faint idea of the astonishing rapidity with which changes are accomplished in the nervous system. We also ascertain from these experiments that in the small *recurrent* nerves two sets of motor filaments are included,—one set transmitting the nervous influence which stimulates the opening muscles of the *glottis* to act synchronously with the other muscles of inspiration, the other set transmitting the nervous influence which stimulates the closing muscles to act synchronously with the other muscles of expiration. And when we remember that these filaments arise near each other, and from the same medullary tract of the spinal chord, this would furnish us with an additional proof (if any more were necessary) of the futility of attempting to explain sympathetic or associated actions by mere nervous connections.

From all these experiments, then, upon the laryngeal nerves, we are inclined to draw the following conclusions:

1. That the superior laryngeal furnishes one muscle only with *motor* filaments, viz. the *crico-thyroid*.

2. That the superior laryngeal furnishes all, or at least nearly all, the *sensitive* filaments of the *larynx*, and also some of those distributed upon the *mucous surface* of the pharynx.

3. That the inferior laryngeal or recurrent furnishes the *sensitive* filaments to the upper part of the trachea, a few to the *mucous surface* of the pharynx, and still fewer to the *mucous surface* of the larynx.

4. That when any irritation is applied to the mucous membrane of the larynx in the healthy state, this does not excite the contraction of the muscles which move the arytenoid cartilages by acting *directly* upon these through the mucous membrane, but that this contraction takes place by a *reflex action*, in the performance of which the superior laryngeal is the *sensitive*, and the inferior laryngeal is the *motor* nerve.*

Does Section of the Laryngeal Nerves prevent the ingress of the food into the Larynx during Deglutition.—All the *four laryngeal nerves* were divided in two dogs, and four rabbits. Both dogs and two of the rabbits swallowed solids and fluids readily, and without exciting cough or difficulty of breathing. The other two rabbits refused the milk, but they swallowed solids without inconvenience. All these animals were carefully examined after death, and not the slightest trace of the food could be detected in the air-passages. From these experiments it would appear that if the closing muscles of the glottis can, as Magendie has shown, prevent the entrance of food into the larynx after removal of the epiglottis, the epiglottis can, on the other hand, prevent the ingress of food into the larynx, when the movements of all the muscles which diminish the size of the glottis have been suspended by section of the laryngeal nerves.

Effects of Section of the Laryngeal Nerves upon the Voice.—In the experiments upon the two dogs mentioned above, and others which we might adduce, in which the superior laryngeal nerves were cut, I could detect no change upon the voice. I will not by any means maintain that no change was effected, for my perception of differences in sound is far from being good. Since the variations in the length of a tube alter the graveness and acuteness of the sounds which it emits, we would expect that section of the *superior laryngeal* should, by arresting the movements of the *crico-thyroid* muscles, produce some change in this respect. Magendie† mentions that an animal, after section of the *superior laryngeal* nerves, "loses almost all its acute sounds; it acquires besides a constant gravity, which it had not previously." This he attributes to the arrestment of the movements of the *arytenoid* muscles. But we have shown that section of these nerves has

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* The functions of the œsophageal filaments of the *recurrent* will be examined along with the other *œsophageal* filaments of the *par vagum*.

† Oper. cit. p. 138.

no such effect. Supposing Magendie quite correct* in the occurrence of this change of the voice, may it not be explained in this manner. He himself states,† that during acute sounds, the vocal tube is shortened, and lengthened during the formation of those which are grave. Now section of the superior laryngeals would necessarily have the effect of preventing the tube from being so much shortened as during the natural action of the parts; in other words, it might prevent the production of the acute sounds; and may not the relaxed state of the *crico-thyroid* muscles be one of the conditions necessary for the production of a grave sound?

With regard to the effects of section of the recurrent upon the voice,—a physiological experiment which has been performed so very frequently since the time of Galen, we have no observations to make. We may merely remark, that we found, as the second Monro‡ has stated, that the voice is not altogether lost, for we ascertained that the animal, in some cases at least, could still emit a very faint howl.

It is not my object here to examine the various combined contractions of the muscles of the larynx, which these laryngeal nerves effect,—whether instinctively or sympathetically, as in natural or inarticulate language, and in the function of respiration; or voluntarily, as in artificial or articulate language. Of the great disturbance of these important functions, which either necessarily or occasionally arises from section of these nerves, we have had abundant proof. Perhaps the most interesting of all the associated movements of these muscles to the practical physician, are those connected with the respiratory function, as they promise to throw light upon some important forms of disease. Since these movements were first pointed out by Legallois,§ they have been repeatedly observed in the lower animals by several experimenters; and by Mr Mayo‖ and Sir C. Bell,¶ in individuals of the human species, after unsuccessful attempts at suicide. The energy and extent of these movements, when the respiration is much hurried by the struggles and pain of the animal, appear quite astonishing when witnessed for the first time. When the respiration, however, is such as is natural in a state of rest, the sides of the glottis remain quiescent, or at least nearly so.** The manner in which section or compression of the laryngeal nerves arrests these movements is well illustrated by Exp. XX.

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* Bischoff (Oper. cit. p. 27.) says "duobus canibus *laryngeum superiorem* utrimque dissecui; sed neutrius canis vox nec post plures quidem dies mutata est."

† Oper. cit. p. 139. ‡ Observations on the Nervous System, p. 65.

§ Sur le Principe de la Vie, p. 197. ‖ Medical Gazette, Vol. xiv, p. 22.

¶ Nervous System, p. 484, ed. 3. or Phil. Trans. 1832.

** Legallois and Mayo, oper. cit. It is probable that when the larynx is small, as in young animals, these movements are constant, even when the respiration is not hurried.

and XXI. From these we learn, that when the inferior laryngeal nerves are cut, all the movements of the muscles of the arytenoid cartilages are arrested, and the superior aperture of the glottis can no longer be dilated during inspiration. In fact, the sides of the *glottis* are not only no longer separated by an active force, but they are rendered quite passive, and yield readily, within certain limits, to the slightest external force applied to them. The *glottis* now presents the appearance which it does some time after death; indeed it is probably still more diminished in size, for as the contractility of the muscular fibre is unimpaired by section of the nerves, their tonicity may still occasion further diminution, since the strength of the closing, preponderates over that of the opening muscles. When the *recurrent* nerves are cut in an adult animal, where the aperture of the *larynx* is large, a quantity of air may still find its way through the diminished aperture of the *glottis*, adequate in many cases to carry on the respiratory process in a sufficient manner, particularly if the muscles of inspiration are not acting violently. If, on the other hand, the capacity of the *larynx* is proportionally smaller, as in young animals, the air rushes through the diminished aperture in a narrower stream and with increased force, more especially when the inspiratory movements are violent,—or, in other words, when the capacity of the thorax is suddenly and greatly enlarged,—and the consequence is, that an insufficient quantity of air reaches the lungs. This quantity is still further reduced, by the circumstance, that the now passive sides of the superior aperture of the glottis are carried inwards by the current of air, as in Exp. XX. where it was remarked that, at each inspiration, the arytenoid cartilages were so closely approximated, as almost entirely to prevent the ingress of air, and where it was necessary to hold aside the edges of the superior aperture of the *glottis*, to prevent the immediate suffocation of the animal. It is the inspiration alone of the animal which is difficult, for the expiration is easy. The *arytenoid* cartilages are readily pushed aside by the expired air. The occurrence or non-occurrence of dyspnœa or suffocation after section of the *inferior laryngeals* is to be explained by the greater or less capacity of the larynx in the individual animal, and the violence of its respiratory movements at the time. The crowing sound which frequently attends this condition of the laryngeal muscles is of course a mere physical effect, and depends upon the current of air rushing rapidly through the diminished aperture of the glottis, and may be imitated in the larynx of a dead animal. It is evident, then, that we must again return to Legallois's explanation of the cause of the *dyspœna* after section of the *recurrent* nerves, which I have been here illustrating and extending. For though this acute physiologist does not enter upon the consideration of the relative share

which these nerves have in the movements of the *intrinsic muscles* of the larynx, yet he distinctly attributed the dyspnœa after the section of the recurrents to muscular paralysis.* He also explained the manner in which the arytenoid cartilages are carried inwards by the current of air passing through the *glottis*, from what takes place when a syringe is fixed to the trachea,—detached with the larynx,—from the body after death, and the air drawn forcibly downwards. At each stroke of the syringe, the edges of the superior aperture of the glottis are approximated, and if the current of air is strong, the aperture is completely shut.†

Whether the crowing disease of children, or *laryngismus stridulus*, depends upon the movements of the muscles of the glottis being suspended by compression of the *recurrents* or of the *pneumogastrics* themselves above the origin of these branches, by enlarged glands, as the late Dr Ley supposed, or whether, as is more generally imagined, it depends upon a *spasm* of these muscles, and "is obviously a part of a more general spasmodic affection,"‡ it is not for me to determine. From the experiments we have detailed it is, however, apparent, that severe dyspnœa amounting to suffocation may arise both from irritation and compression of the inferior laryngeal nerves, or the trunks of the *pneumogastrics*. For when both or even one *recurrent* nerve was irritated, the *arytenoid* cartilages were approximated so as in some cases to shut completely the superior aperture of the *glottis*; and we have already explained at some length how paralysis of this nerve, occasioned by compression or any other cause, should produce this effect by arresting all the movements of the muscles of the *glottis*. We shall leave it to those who have had frequent opportunities of seeing this disease, to determine which of these two causes will best explain the phenomena which it presents. There appears, however, to be little doubt, that the crowing respiration and dyspnœa which accompany some cases of hysteria, depend upon a spasmodic closure of the *glottis*, produced by some irritation of the *recurrent* nerves.

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* C'est donc bien réellement en paralysant les muscles aryténoïdiens et en relâchant par là les ligaments de la glotte, que la section des nerfs recurrens produit la suffocation." Whether Legallois by the term arytenoid muscles, here means the muscles universally known by this name, or whether he erroneously extends it to all the muscles attached to the arytenoid cartilages, I have not been able to ascertain from his writings.

† In performing this experiment, care must be taken to produce a large and rapid current of air, such as we would suppose to pass through the larynx when the chest is rapidly and fully dilated in a violent inspiration. If the syringe employed is one of moderate size, a small larynx must be selected, otherwise the experiment will fail.

For an excellent exposition of the principal conditions of the system under which violent inspirations are apt to be made, or, in other words, when the aperture of the glottis is likely to be most diminished, see Dr Ley on Laryngismus Stridulus, p. 85.

‡ Dr Marshall Hall's Lectures on the Nervous System, p. 76, 1836.

Œsophageal Branches of Par Vagum.—It is obvious that, as the *œsophageal* branches of the *par vagum* cannot be divided separately, we can only ascertain the functions of these by cutting the trunk of the *par vagum* itself in the neck.

Effects of the irritation of these nerves in an animal recently killed.—I have repeatedly seen violent muscular contractions induced along the whole length of the tube of the *œsophagus*, by mechanical or chemical irritation of the trunk of the *par vagum* in *dogs*, *rabbits*, and *cats*. At each application of the irritant, the *œsophagus* became shortened, and diminished in calibre. These movements extended also to the *cardiac* extremity of the stomach. In the stomach they were evidently more slow, prolonged, and vermicular, than in the *œsophagus*. They extended somewhat slowly from the cardiac orifice, over a greater or less extent of the left portion of the stomach. In one case they were more extensive and rapid than in the others, but still retained somewhat of their vermicular appearance. Muscular contractions of the œsophagus on irritating the *par vagum* in an animal recently killed, have been observed by Arnemann,* Cruikshank,† and Mayo.‡ Mr Mayo could not perceive any muscular movements of the stomach upon irritating this nerve. These were, however, frequently observed by Tiedemann and L. Gmelin.§ They have also been inferred by Brechet and Dr M. Edwards,‖ from the effects of galvanising the lower ends of the cut *pneumogastrics* in the neck on the living animal.

Effects of section of the œsophageal branches upon the movements of the oesophagus.

Exp. XXII.—A portion of the *par vagum* was removed on both sides, high in the neck, in a rabbit which had fasted sixteen hours. The portions removed included the *second* ganglion of the *par vagum*, and consequently the origin of the *superior laryngeals*. The respiration continued heaving, and somewhat difficult for a short time, but it soon became pretty easy. Some parsley was now thrown down on the opposite side of the room, which it immediately made for, and began to eat. It appeared to swallow the first mouthfuls readily, and without inconvenience. As it continued to eat, its breathing again became heaving, and it apparently felt very uneasy. It was soon after seized with attempts to vomit or cough,¶ and retired from its food. After a

* As quoted by Soemmerring, oper cit. Tom. iv. p. 272.
† Medical Facts and Observations, Tom. vii. p. 153, or Phil. Trans. 1795.
‡ Mayo, Anatomical and Physiological Commentaries, No. ii. p. 15.
§ Recher. Exper. Physiol. et Chem. sur la Digestion, &c. p. 374.
‖ Archiv. Gen. de Med. Tom. vii.
¶ It certainly presented much more the appearance of a cough than an effort to vomit. As, however, apparently similar muscular movements have been described by late experimenters, as an effort to vomit, and the possibility of the excitation of

short time the *dyspnœa* abated somewhat, and it returned to eat. It had only swallowed a small quantity, when the uneasiness, *dyspnœa*, and efforts to vomit, became as urgent as before. Every time it returned to eat (and it did this several times) these were always much increased in severity; so that it more than once appeared dying from suffocation. The breathing was now constantly very difficult, with a rattling sound in the *trachea*. Five hours after the section of the nerves, it again approached the parsley, but it had only eaten a very short time, when it sprung into the air, and after making violent struggles, and apparently suffering great uneasiness for nearly a minute, it died.—*Dissection*. This was done immediately after death. The nerves were found fairly divided. On exposing the trachea in the neck, I was struck with the great size of the œsophagus, which was distended like a sausage, and evidently compressed the trachea. The green colour of the parsley was quite distinctly seen through the coats of the œsophagus. The pharynx contained some parsley, but was by no means filled by it. The œsophagus in the thorax was distended, in the same manner as in the neck, down to the stomach. The stomach was well filled, but was certainly far from being unnaturally distended, and could have easily held more in its pyloric extremity. Considerable quantities of the masticated parsley were found in the larynx, trachea, and bronchi. In some parts of the lungs it was found in the minutest air-cells, and one or two portions were perfectly dense, from the quantity which they contained.

Exp. XXIII.—The *pneumogastrics* were cut above the origin of the *superior laryngeals* in another full grown rabbit, after fasting twenty-four hours. This was followed by pretty severe dyspnœa and uneasiness. It refused for sometime to eat the parsley laid before it. When it began to eat, it was observed that it swallowed the first mouthfuls perfectly, and without any additional uneasiness. As it continued to eat, it became restless, and was affected similarly to the animal in the preceding experiment. The breathing after this continued very difficult, and it made but very few subsequent attempts to take food. It was seen alive ten hours after the section of the nerves. It was found dead next morning.—*Dissection*. The *œsophagus* was distended by the parsley, though not to the same extent as in the preceding experiment. The calibre of the *trachea* was also evidently somewhat diminished by the stuffed *œsophagus*. The stomach contained a moderate quantity of food, but was by no means fully

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[t]he sensation which induces coughing, under such circumstances, has been strongly denied, I will not at present venture an opinion on this question, until I have examined it more thoroughly. We shall call it in the meantime an effort to vomit. We could not expect a perfect cough in an experiment of this kind, after the movements of the muscles of the glottis had been arrested.

distended. A small quantity only of the masticated parsley was found in the air tubes.

We believe that in these two experiments, the first mouthful was carried into the upper portion of the *œsophagus* in the usual manner, but as the muscular movements of this tube had been suspended, it remained there. As additional mouthfuls arrived, they propelled forwards those which preceded them, so that after a while these formed a column of food reaching from the lower part of the pharynx to the stomach. As the difficulty of propelling it into the stomach increased, the œsophagus became more distended, and pressed upon the trachea, and thus produced the *dyspnœa*, and uneasiness. The difficulty of propelling the food still increasing, it accumulated in the *pharynx*, and passed into the open *larynx;* hence the severe paroxysms of *dyspnœa* and suffocation in Exp. XXII. Its passage into the *larynx* was, in the two experiments we have just related, much facilitated by the section of the *laryngeal* nerves. It is important to observe, that in these experiments, the stomach was found after death to contain only a moderate quantity of food, notwithstanding the great distension of the *œsophagus*.

This distension of the *œsophagus* after section of the *par vagum* in the neck has been remarked by several observers. Some of these have contented themselves with the simple statement of the fact; others have attributed it to paralysis of the *œsophagus;* while others again have referred it to other causes. Baglivi in one experiment found the œsophagus distended through its whole length, and though he does not state that he attributed this to paralysis of the œsophagus, yet it is probable, that this was his opinion; for after stating the circumstance, he adds, "nam cibus in ventriculum descendere non poterat."* Valsalva has also observed this retention of the food in the œsophagus, and it is likewise probable that he believed that it depended upon the same cause; for after mentioning that he dissected a dog which died on the tenth day after section of these nerves, and which had vomited frequently, he states, "quidquid autem cibi postremis diebus retinuerat, id omne intra œsophagum ab hujus initio ad sinistrum usque orificium ventriculi, nulla ejus facta mutatione, continebatur."† Dupuy distinctly refers this retention of the food in the œsophagus to its paralysis.‡ In several experiments upon the effects of section of the *pneumogastrics* in horses, he ascertained that the œsophagus was distended, while the animals were still alive. That the œsophagus is really paralysed, it is easy, he says, to convince ourselves, "en mettant l'œsophage à

* Opera omnia, p 676, Anvers. 1715.

† Valsalvæ Opera cum Epistolis Anatomicis, &c. J. B. Morgagni, Epist. Anatom. xiii. 37, Venet. 1740.

‡ Journal de Médecine Chirurgie, &c. Tom. xxxvii. p. 351.

découvert. Si on fait boire l'animal, on n'apperçait aucun mouvement dans la membrane charnue de l'œsophage," &c. Sir A. Cooper * in his late experiments on the *par vagum*, after mentioning this retention of the food in the œsophagus, also refers it to paralysis of that tube. Several experimenters, however, explain this distension of the œsophagus differently. The late Mr Broughton maintained, that " the parsley found in the œsophagus must be the result of ineffectual efforts to throw it off the stomach." † Dr Wilson Philip also maintains the same opinion.‡ Brachet seems to think that the œsophagus becomes filled in consequence of the animal having lost the sense of satiety, and continuing to eat after the stomach has been distended to the full. § In another place he seems to admit that the lower part of the œsophagus may be paralysed. ‖ Some others seem to think that since the cardiac orifice of the stomach is paralysed, the food is readily forced from the stomach into the œsophagus. On reviewing Experiments XXII. and XXIII., and those which we have referred to above, it is at once apparent, that they are not sufficient, with the exception, perhaps, of those of Dupuy, fully to invalidate the explanation in which it is maintained, that the distension of the œsophagus depends upon the food being forced back from the stomach. Both of the animals we experimented on, made very frequent efforts to vomit after eating. It was, therefore, necessary to perform the experiment in another way.

Exp. XXIV.—The *pneumogastrics* were cut in the neck, as in the two preceding experiments, in two full-grown rabbits, which had been made to fast for twenty-six hours. Though the breathing of these animals was not difficult, it continued to be evidently somewhat heaving. About an hour after the section of the nerves, a quantity of parsley was offered to one of them, and it began immediately to eat. The first mouthfuls were swallowed without any change upon the breathing. Gradually, however, the breathing became more hurried and laboured as it continued to eat, and when the dyspnœa had become pretty urgent, it was instantly deprived of life by a blow upon the head, and before it had given the slightest indications of any effort to vomit.—*Dissection.* This was performed immediately after death. The *œsophagus* was found filled throughout its whole length with parsley, and it had evidently diminished the calibre of the *trachea*. The *stomach* contained but a very moderate quantity of food, and this when examined was found to consist principally of substances taken the previous day. In fact, a quantity of parsley, not exceeding a few leaves, was all that

* Guy's Hospital Reports, Sept. 1836.
† Quarterly Journal of Literature, Science, &c. Vol. x. p. 13.
‡ Experimental Inquiry, &c. p. 112, ed. 3d.
§ Système Nerveux Ganglionaire, &c. p. 180, 1830. ‖ Oper. cit. p. 204.

had reached the stomach, and was quite easily distinguished from the old food. This was lying between the outer surface of the old food and the inner surface of the *cardiac* extremity of the *stomach*. Not the slightest traces of the parsley could be found in any of the air-passages. On first exposing the distended *œsophagus*, it was observed that irritation of the *lower* end of the cut *pneumogastrics*, both by the forceps and galvanism, produced vigorous contractions of the muscular fibres of the *œsophagus*, which extended over the *cardiac* portion of the *stomach*. A similar experiment was performed on the second rabbit, about two hours after section of the nerves, with exactly the same results. The same movements were also observed in the œsophagus and stomach, on irritating the lower end of the cut nerves. Dr Alison witnessed the dissection of the first rabbit, and the experiment and dissection of the second.

We believe that these experiments prove quite satisfactorily, that the *œsophagus* is distended before the *stomach*, and also fully bear out the explanation of the phenomena arising from the retention of the food in this tube which we have given above. It must be remembered that when the *pneumogastrics* are cut in the neck, even as high as the origin of the *superior laryngeals*, that the pharynx, and a very small portion of the œsophagus next to it, still retain their healthy action, for, as we have already seen, these receive their motor filaments from the *pharyngeal* branches of this nerve. These parts then continue to act, and propel the food down the passive *œsophagus*, as they would force it into any inorganic tube. That food should also be sometimes found in the *œsophagus* after death in some of those animals which have not fed subsequent to the section of the nerves, is also exactly what we would expect. For it is evident, that if efforts at vomiting come on, the powerful contractions of the abdominal muscles will force the food into the paralysed *œsophagus*. It could also easily be shown that the powerful contractions of the abdominal muscles necessary for coughing would also force the food from the stomach into the *œsophagus*.

This arrestment of the movements of the muscular fibres of the *œsophagus* in deglutition after section of the *pneumogastrics*, when taken along with the fact observed in the two last experiments, proves, that this does not depend upon any diminution in the contractility of these muscular fibres, but upon a breach being made in the nervous circle, which, through the intervention of the *medulla oblongata*, connects the muscular with the mucous coat. We, therefore, conclude that the muscular contractions of the œsophagus are not called into action by the ingesta acting directly as an excitant upon the muscular fibres through the mucous membrane, but by a reflex action, part of the *œsophageal* filaments of

the *par vagum* acting as motor, and others, in the manner of sensitive nerves.* We believe that this fact affords a more satisfactory solution than has yet been offered of a physiological problem which has lately excited a good deal of attention, viz. whether any of the sympathetic actions of Whytt, the ("excito-motory actions" of Dr M. Hall,) can take place without the intervention of a sensation. The food is propelled along the œsophagus without our consciousness and without our volition, and yet we have seen, that, before the presence of the ingesta in this tube can excite its muscular fibres to contract and propel their contents onwards, the same conditions of the nervous system are necessary, as for the production of those sympathetic or instinctive actions which are not excited by mental acts.† For, First, an impression must be made upon the nervous filaments of the *œsophageal* branches ramified in the mucous coat. Secondly, This impression must then be transmitted along these filaments to the central organs of the nervous system. Thirdly, Some other change must be transmitted backwards from the central organs of the nervous system (in this case the medulla oblongata) along the motor filaments to the muscular coat, by which the stimulation and consequent contraction of the muscular fibres are produced.‡ We have here, then, a natural sympathetic action in the human body occurring without the intervention of a sensation, and simply because the presence of such a sensation is not necessary for the proper performance of this function. From this and other facts which have been adduced in discussions on this question, I think we are fully entitled to argue that sensation is not a necessary condition for the production of those sympathetic actions with which it is so closely linked. Besides, it can be shown that these sensations have been connected with their attendant movements for an evident purpose; and if this purpose is one which is not necessarily instrumental in the production of the movements themselves as muscular movements, but to further the ends for which they were designed, we have already succeeded in obtaining a sufficient reason for the presence of these sensations, without being obliged to believe that they are actually concerned in the production of these movements. To illustrate my meaning by an example;—when the *bladder* and *rectum* are filled by their usual contents certain

* Or, to use the phraseology of Dr M. Hall, the contraction of the œsophagus in deglutition is an excito-motory action—the filaments of the œsophageal nerves distributed in the mucous coat being the excitors, and those in the muscular coats being the reflex or motors.

† Among the sympathetic or instinctive actions which require the intervention of a mental act, or the excitation of a sensation, we may enumerate laughter, weeping, &c. These require the agency of the brain for their performance.

‡ Mr W. B. Carpenter has given a very excellent tabular arrangement of the voluntary and instinctive actions, accompanied with some very perspicuous remarks. Number 132 of this Journal.

impressions are made upon the *spinal* sensitive nerves distributed in their mucous coat, and these, when conveyed to the central organs of the nervous system, excite certain sensations; upon this certain muscular movements follow, by which the contents of these organs are expelled. Now the presence of the sensations is no absolute proof that their excitation is necessary for the performance of these muscular movements, for it must be at once obvious, that they here serve most important purposes, independent of any supposed influence exerted in the actual production of the movements. For if these muscular movements by which the contents of the rectum and bladder are expelled, were always to occur when the impressions were made, very serious inconveniences would evidently be occasioned. It is necessary, then, for our own comfort and well being, that these movements should be influenced to a very considerable extent by volition; and of course this could only be accomplished by associating sensation with the excitation of the impression. When we take these circumstances along with the experiments we have stated, we may, I believe, safely conclude, that these sensations are not concerned in the production of these movements, as muscular movements, but have been superadded for an ulterior purpose. The same kind of reasoning could easily be applied to all the other instinctive and sympathetic actions found conjoined with sensation in the healthy condition of the body, but which do not require the intervention of the brain for their performance.*

The results obtained from these experiments upon the œsophageal branches of the *par vagum*, are at direct variance with the Hallerian doctrine, that the muscular fibres of the œsophagus are called into contraction by a direct impression. Though this does not occur in the healthy condition, it is probable that both the muscular fibres of the œsophagus, and also the principal closing muscles of the glottis, may be called into action by a direct impression, when the mucous surfaces of these organs are inflamed. For we find in many cases of disease or injury of the spinal chord,

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* These sympathetic or "excito-motory movements" were well known, and described by Whytt and Monro. That some of them do not require the agency of the brain for their performance was clearly proved by the experiments of Blane, Legallois, Flourens, and others. It was also stated previous to the appearance of the publications of Dr M. Hall, that these movements were independent of *sensation*. Sir G. Blane, for example, when relating the experiments referred to above, states, "that there are facts which show that instinctive actions, even in animals endowed with brain and nerves, do not depend on *sensation*. (Lectures on Muscular Motion, read at the Royal Society in 1788.) Dr M. Hall, availing himself of the late discoveries, by which it has been shown that the nervous filaments which transmit impressions to the central organs of the nervous system, are distinct from those which convey the motive influence back to the muscles, has extended and more fully illustrated this view of the independence of these sympathetic movements upon sensation, and has formed it into a kind of Corps de Doctrine.

that the bladder ceases to expel its contents. In some of these cases, as I have myself seen, the urine after a time no longer requires to be drawn off by the catheter, but is constantly expelled as soon as it has accumulated in small quantities. On dissection of such cases after death, the mucous coat is found thickened and inflamed, and the muscular coat is greatly increased in strength and contracted upon itself. We believe that the explanation of such cases is this, that as long as the mucous coat is in a healthy condition, the urine fails to excite the action of the muscular coat by a direct impression, but when the former becomes inflamed this is effected.

The arrestment of the movements of the *œsophagus* in deglutition after section of the *par vagum* completely invalidates the evidence adduced by Brachet,* in favour of the dependence of the sense of satiety upon the integrity of the *par vagum*. We do not wish to deny that this may be the case; we only mean to affirm that the data upon which Brachet rests his conclusions are obviously insufficient.

Cardiac branches of Par Vagum.—It may be considered as perfectly ascertained by numerous observers, that section of the *par vagum* above the origin of the cardiac branch of this nerve does not materially affect the heart's action, and that the sudden death occasionally remarked after the division of these nerves, and which some of the early experimenters attributed to arrestment of the action of this organ, was in fact dependent upon the suffocation of the animal, by suspending the movements of the muscles of the glottis. We may then, I believe, fairly attribute the increased frequency of the pulsations of the heart, observed during and for some minutes after the experiment, to the struggles and terror of the animal, for in a short time the action of the heart is as slow and vigorous as before the section of the nerves. Though the contractility of the heart is independent of the brain and spinal marrow, yet we know, from the experiments of Legallois, Wilson Philip, and others, that injuries of these organs influence the contractility of the heart in a most important manner. A sudden injury extending to a considerable portion of the brain arrests or at least much enfeebles the heart's action, and the extent to which the contractions of this organ are affected by mental emotions is well known. It is generally believed that it is through the cardiac branches of the *par vagum* that this influence is transmitted from the brain to the heart; but I am not aware that there are any decisive facts in proof of this opinion.

Exp. XXV.—Two rabbits were killed by crushing the brain extensively and suddenly by blows with a hammer. In one of

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* Oper. cit. Exp. 50 and 53.

these a portion of each of the pneumogastrics above the origin of the superior laryngeals had been removed. On exposing the heart of the rabbit in which the nerves were left entire, which was done as expeditiously as possible, these contractions of the heart were extremely rapid and very feeble. On exposing the heart of the animal, in which the nerves had been previously cut, which was also done immediately after the brain had been crushed, the action of the heart was evidently much slower and more vigorous than in the other animal. This comparative experiment was again repeated with the same results. The action of the heart was also examined in other two rabbits, on which the pneumogastrics had also been previously divided in a similar manner before the brain was crushed, and in neither of these did it present the same rapid and feeble movements, which I have always seen when these nerves were entire.* Now since the contractility of the heart can also be effected by extensive and sudden injury of the spinal chord after the brain has been removed, it would appear that the influence of causes acting on the central organs of the nervous system may be transmitted to the heart by two channels, viz. by the *par vagum*, and by the *sympathetic system*. In these experiments, the trunk of the sympathetic in the neck was divided along with the *par vagum*, but this of course could not affect the greater number of the sympathetic nerves passing to the heart.

Pulmonary Branches of the Par Vagum.—The only method of experimenting on the pulmonary branches of the *par vagum* which we can adopt in the living animal, is that of cutting the trunk of the nerve itself, as it lies in the neck.

Effects of Section of one Pneumogastric Nerve upon the Lung of that side.—About two years ago I commenced, at the suggestion of Dr Alison, a series of experiments upon the effects of section of the *pneumogastric* nerves upon the *respiratory murmur*, as it might probably enable us to ascertain what is the cause of the first departure from the healthy condition of the lungs after section of these nerves. As I was led by the statements of Wilson Philip† to believe that section of one of the *pneumogastrics* would produce the usual morbid changes in the lungs which are observed after the section of both, and by the results of the experiments of Magendie‡ and Mr Swan,§ to expect that these would be confined to the side operated upon, I selected this method of experimenting, as the sound lung in that case would afford an accurate standard of comparison, by which to judge of

* Dr Alison was present at one of these experiments, and made the same remark.
† Oper. cit. p. 145. ‡ Oper. cit. 401.
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the changes effected. No doubt the well-known experiment of Haighton* is inconsistent with the supposition, that section of one of the nerves destroys the function of the lung on the same side; but as he simply divided the nerve without removing a portion of it, the re-union of the cut ends might have occurred before a sufficient time had elapsed to permit these morbid changes to be effected. I have removed a portion of the *par vagum* in fourteen animals, and have never yet observed any morbid structural change which I could attribute to the section of the nerve. Two of these were calves, and were killed about twenty-four hours after the section of the nerve: seven of them were dogs, and were allowed to live from four to ten days: three rabbits were allowed to live a fortnight: one rabbit lived three months, and one rabbit was killed after six months. None of these animals appeared to suffer any bad consequences from the operation. The dogs breathed easily, and ate and digested as before; the rabbits also were as lively and active as ever, after the operation. No morbid changes, as I have said, could be observed in the lungs of the calves and dogs after death. The three rabbits which were allowed to live for a fortnight were apparently in perfect health when killed, and the lungs were shown to my friend Dr Knox, who was at the same time requested to examine if there was any structural difference between the lungs of the opposite sides, but he could perceive none. The rabbit which lived three months died of recent pneumonia, affecting *both* lungs equally. The lungs of the rabbit killed at the end of six months were perfectly healthy. In all these experiments, a sufficiently large portion of the nerves was removed to prevent their re-union. The morbid changes on the lung in the side on which the nerve had been cut, observed by Magendie and Swan, must have been accidental. The experiments which I have mentioned are sufficiently numerous to entitle us to conclude, that lesion of one of the pneumogastrics does not necessarily, or even generally induce disease of the lung of that side. This does not appear so remarkable, when we remember the free anastomoses between the pulmonary plexuses of the two sides.

Effects of Section of the Par Vagum upon the respiratory muscular movements.—As the pulmonary branches of the pneumogastrics are the only nervous filaments which the lungs receive from the cerebro-spinal axis, we would expect, in accordance with the generally received notions on the physiology of the nervous system, that all the impressions made on the mucous surface of the lungs which excite the sensations and sympathetic movements connected with the respiratory functions, are conveyed to the cerebro-spinal axis through this nerve. And this opinion is strengthen-

* Medical Facts and Observations, Vol. vii. p. 163. Experiment IV.

ed by the experiments of Legallois and Flourens, by which it was shown, that though all the other parts of the encephalon above that portion of the *medulla oblongata* to which the *par vagum* is attached, could be removed without arresting the respiratory muscular movements, yet these instantly ceased, when this part of the nervous system was injured. And it is further well known, that if the spinal marrow is cut across, all the respiratory muscles are paralysed which receive their nerves from that portion of the spinal chord below the point divided, while those which receive their nerves from that portion of the spinal chord which remains in connection with the *medulla oblongata*, continue to perform their usual functions. From these and other facts, it may be considered as ascertained, that all the impressions made at the lungs must be conveyed to the *medulla oblongata*, before they can excite sensations or sympathetic movements. That the *par vagum* can convey these impressions from the lungs, is not only rendered probable by the connection of the *par vagum* with the *medulla oblongata*, but may be considered as proved by the results of the experiments upon section of the spinal chord, to which we have just referred. It, however, by no means necessarily follows, that this is the sole channel by which these impressions are conveyed to the *medulla oblongata*, for it is possible that these might reach the spinal chord through the branches of the sympathetic distributed upon the lungs, and in this way be conveyed upwards to the *medulla oblongata*. This last supposition is certainly not a very probable one, and can only be admitted after satisfactory evidence in its favour.

We shall now examine how the facts accord with the theories on this question. That the respiratory movements continue after section of both pneumogastrics is now universally admitted, but physiologists are by no means agreed in what manner these proceed. Those who believe that the movements of the respiratory muscles are usually carried on by the exercise of volition, will of course maintain, that these proceed exactly in the same manner as before the section of the nerves. This being, however, an untenable supposition, we shall not discuss it further. Those, on the other hand, who maintain that this function, though capable of being influenced and controlled to a very considerable extent by volition, is nevertheless generally performed without our volition, and in consequence of impressions made at the lungs and conveyed to the *medulla oblongata*, must of course believe that this function is carried on differently after section of these nerves, from what it is in the natural condition of the body. Brachet asserts that an animal continues to breathe after section of the pneumogastrics, because it has acquired the habit of using the respiratory muscles.*

* Oper. cit. p. 132 "à l'habitude que le système nerveux cérébro-spinal a contractée de faire mouvoir les muscles respirateurs." How an animal could contract the habit of performing an *involuntary* action, it would certainly be difficult to explain.

Dr Marshall Hall believes that when these nerves are divided, the function of respiration is no longer an involuntary and a sympathetic movement, or, as he expresses it, *excito-motory*, but is now a cerebral function, or, in other words, is performed by an act of volition.* That these movements continue after section of the *pneumogastrics*, and under circumstances where it is impossible that they can be carried on by an act of volition, I have been reluctantly compelled to believe. For I am satisfied that these respiratory movements will not only go on regularly and vigorously for hours together in kittens one and two days old, but that they will also proceed in animals deprived of all volition by a small dose of prussic acid.† Thinking that it might be possible, though certainly not probable, that the impressions made at the lungs might in these cases reach the *medulla oblongata* through the free anastomoses between the laryngeal nerves at the larynx (for in the first experiments I cut the nerves, as is generally done, in the middle of the neck,) I proceeded to repeat the experiments by dividing the nerves near the base of the cranium, and above the origin of the superior laryngeals. The results, however, were the same as when the nerves were cut in the usual manner.

We are next naturally led to inquire, how the *sensation arising from the want of fresh air in the lungs*, or the *besoin de respirer*, is affected by section of these nerves? Brachet‡ has related some experiments, which appear to prove in a very conclusive manner, that this *besoin de respirer* is annihilated by section of the pneumogastrics. Though I considered the details given by Brachet as not satisfactory on some points, yet, after reading them, I had no doubt of the accuracy of his opinion. I am now, however, perfectly satisfied, from numerous experiments, that an animal will continue to evince great uneasiness after section of these nerves, when the access of air to the lungs is prevented. I have repeated these experiments in several ways, and with the same results. One of the methods followed was this.

Exp. XXVI.—The *par vagum* was cut on both sides in two kittens ten days old. When one of these nerves was cut, the blood in the carotids became dark-coloured, but it soon after resumed its natural appearance. When both nerves were cut, the blood in the carotids again became dark, the animal began to struggle, and it was necessary to open the trachea to prevent their immediate suffocation. After the trachea was freely opened, the blood in the carotids again assumed its arterial colour. Both animals struggled, made violent inspirations, and appeared to suffer great uneasiness when the access of air to the lungs was prevent-

* Philos. Mag. Jan. 1835, and Lectures on the Nervous System, p. 25.

† In one dog in which these nerves were divided, the respiration continued above twenty minutes after we had satisfactory evidence that the sensorial functions were arrested.

‡ Oper. cit. p. 133-4-5.

ed. On compressing, for example, the exposed trachea with the forceps, the animals lay quiet for a few moments, making several inspiratory efforts gradually increasing in force and extent; after a few moments more, the inspirations became heaving, and they began to struggle and appear very uneasy.

This experiment was repeated with similar results upon a kitten two days old. The nerves in this last experiment were cut above the origin of the superior laryngeals. I have also performed a similar experiment upon several rabbits and dogs. In all of these animals the breathing became very laboured, and the animal evinced every indication of great uneasiness, when the access of air to the lungs was *suddenly* and *fully* prevented.

From these experiments I conclude that section of the *par vagum* on both sides, neither arrests the transmission of those impressions made upon the mucous surface of the lungs, by which the respiratory movements are excited: nor does it annihilate the sense of anxiety arising from the want of fresh air in the lungs. We are obliged, then, to suppose, that these impressions are conveyed backwards by the sympathetic branches distributed upon the lungs to the spinal chord, and thus pass upwards to the *medulla oblongata*. As has been already stated, we believe that these impressions may also be transmitted through the *par vagum*. It is quite possible that the latter is the usual channel by which these are transmitted, and it is only when they become more intense that they pass along the other course we have mentioned. This may, perhaps, explain the slow respiration occasionally observed after section of the pneumogastrics. It is certainly contrary to the usually received physiological doctrines to suppose that the sympathetic system can, in the *healthy* state of the nerve, and of the parts upon which it is distributed, transmit those impressions by which the natural sensations and sympathetic movements are excited, but I cannot see how the facts can otherwise be explained. The peculiar pain felt on bruising the healthy testicle, and which we are led to believe depends upon the sympathetic, may also induce us to believe that a previously inflamed condition of the filaments of this nerve is not absolutely necessary to enable it to transmit those impressions which excite sensation.

Brachet* has also detailed several experiments which seem satisfactorily to prove that all the sensations occasioned by the presence of foreign bodies, &c. in the air-passages are dependent upon the integrity of the pneumogastrics. I have repeated these experiments on several dogs and cats, but have not yet been able to arrive at any conclusive results. The chief difficulty which I have experienced in making any satisfactory experiments on this question has arisen from the great insensibility of the mucous mem-

* Oper. cit. p. 157-8-9.

brane of the lungs in the healthy state. I have never yet been able to induce the severe paroxysms of coughing described by Brachet, by any mode of irritating the inner surface of the trachea and bronchi which I have adopted, if care were taken to prevent the application of these irritants to the inner surface of the larynx, when the superior laryngeals were entire. I injected by a syringe two drachms of alcohol slightly diluted, down the trachea of one dog, and as much *eau de cologne* into that of another, when both nerves were entire, without exciting any decided cough. The friction of a probe against the inner surface of the trachea and bronchi never produced cough. Though I have seen some reason to doubt that these sensations of the mucous surface of the lungs are affected to the extent stated by Brachet, yet I do not at present wish to offer an opinion upon this subject, until I have investigated it more thoroughly. I would only suggest at present, that it is possible that Brachet in some of his experiments may have overlooked a source of fallacy which would very seriously interfere with the results,—and that is, the facility with which some of the irritants used might reach the interior of the larynx; ~~for~~ it is to be remembered, that the nerves were cut below the origin of the superior laryngeals. If the head be depressed when a quantity of fluid is thrown into the trachea, or if the fumes from a muriatic acid bottle are used as an irritant, (as by Brachet in some of his experiments,) the chances are, that a part of these will reach the interior of the larynx, and excite violent efforts to cough. Perhaps this may explain in some measure the discrepancy between the results obtained by Brachet upon the sensibility of the mucous membrane of the trachea, and those obtained by practical surgeons in operations on the human species, and in some experiments by Haller* upon animals. Some of the animals I experimented on did cough slightly when fluids were injected into the trachea before the nerves were cut,—at least in the imperfect manner in which an animal must do when the trachea is opened.

Morbid changes in the Lungs after section of the Pneumogastrics.—Section of the pneumogastrics invariably proves fatal if the cut ends of the nerves are kept apart. The animal seldom if ever lives beyond three days, and generally dies sooner; but when the cut ends of the nerves are allowed to remain in contact, it sometimes lives ten or twelve days. There can be now no doubt that the section of these nerves proves fatal by its effects upon the lungs. The congested state of the blood-vessels of the lungs, and the effusion of frothy serum into the air-cells and bronchial tubes, may be considered as the characteristic and only constant appear-

* Opera Minora, Tom. i. p. 402, Laus. 1762; or Sur la Nature Sensible et Irritable, Tom. i. p. 391, Laus. 1756.

ance after death from section of the pneumogastrics. I am of course here supposing that the air is allowed to pass freely into the lungs. It is quite evident that section of these nerves does not prove fatal by removing any innervation necessary for effecting the changes by which the venous blood is converted into arterial, as Dupuytren supposed; nor by coagulating the blood of the pulmonary arteries, as Mayer maintains. The first point to ascertain in an investigation of this kind, is the first departure from the healthy condition of the organ,—to decide whether the effusion of the frothy reddish serum, by interfering with the usual changes of the blood in the lungs, causes the congested state of the pulmonary blood-vessels, and the severe dyspnœa, as is usually imagined; or whether this effusion is the effect of a previously congested state of the pulmonary blood-vessels and its attendant *dyspnœa*. If it be made out that the fatal dyspnœa is not the effect of the effusion of serum, we have next to inquire what is the probable cause of this congested state of the pulmonary blood-vessels and the accompanying dyspnœa. I have been collecting for some time past a considerable number of facts on these questions, but have not yet been able to obtain what I consider satisfactory data. Upon the discussion of this subject I shall not at present enter, but reserve it for another opportunity. If I hazard a few remarks upon this question, I wish that they may be looked upon as conclusions in which I myself do not place any very great confidence, until I have been more thoroughly satisfied of their accuracy. I am at present inclined to believe, from the experiments which I have made, that this frothy serous effusion is the *result* of the congested state of the pulmonary blood-vessels attending the severe dyspnœa which precedes death, and not the *cause* of this *dyspnœa*. The grounds on which I have adopted this opinion are these, 1*st*, This frothy serous effusion is exactly similar to the fluid in the air-passages in death from whatever cause, when preceded by protracted and severe dyspnœa. 2*dly*, The extent of this effusion appears to be proportionate to the duration and severity of the dyspnœa preceding death. 3*dly*, Dyspnœa is sometimes present after section of these nerves when the passage of air into the lungs is quite free, and before any serous fluid has been effused. What is the cause of the dyspnœa and congestion of the pulmonary vessels, I have not yet been able to satisfy myself, but I believe it probably depends upon paralysis of the muscular fibres of the bronchi. If these muscular fibres move in unison with the muscles of respiration, like those of the *larynx* supplied by the same nerve, they must exert a very important influence over the renewal of the air in the lungs. That we are not conscious of any such movements cannot be urged as an objection to this view, after what we have seen in the *œsophagus*. Of the exis ence of the muscular fibres of the

bronchi described by Reisseissen there can be no doubt. I have seen these muscular fibres very distinctly in some of the smaller bronchial tubes. I have observed a circumstance in experiments upon dogs, which, if confirmed by more extended investigation, may throw some light upon this question. In four dogs in which the *par vagum* was cut on one side, the respiration of the same side, though quite natural immediately after the operation, became distinctly bronchial after a few hours. This continued for two or three days, and the natural respiratory murmur gradually returned. One of these dogs was killed during the continuance of this bronchial respiration, and no structural change could be detected in the lung. As I have, however, some reason to doubt from late experiments whether this is a constant occurrence, I shall defer its consideration until I have made more extended observations. I am inclined to believe from what I have seen, that pneumonia is a pretty frequent occurrence after section of these nerves.

Gastric branches of the Par Vagum.—As my experiments on these branches are not yet completed, I shall reserve this part of the investigation for a future opportunity.

Part III.—*Spinal Accessory Nerve.*

Before stating the experiments which I have made upon this nerve, I wish to advert for a little to its origin and distribution, and in this I shall restrict myself to those points which are most intimately connected with the discussions upon its functions. The origin of the spinal accessory from the spinal chord is sometimes higher and sometimes lower, but we have the authority of Huber,* Lobstein, † and Bellingeri, ‡ who have attended particularly to this subject, in stating that it most frequently commences opposite the *sixth* or *seventh cervical nerves.* This nerve, in its course upwards to the *foramen magnum*, is placed between the posterior roots of the spinal nerves and the *ligamentum denticulatum*, and receives its filaments, as Bellingeri § has clearly demonstrated, from the lateral or middle column of the spinal chord. The filaments of the *spinal accessory* may come entirely from the *middle column* of the *spinal chord*, or it may also receive some filaments from the posterior roots of the first and second *cervical nerves.* These filaments, from the posterior roots to the

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* Huber says at p. 13, "De Medulla Spinali et Speciatim de Nervis ab ea Provenientibus," that it commences opposite the seventh cervical, but he afterwards places it opposite the sixth.

† Lobstein (De Nervo Spinali ad Par Vagum Accessorio, p. 341, Tom. i. Thesaus. Diss. Sandifort, 1768,) says it commences under the sixth pair of cervical nerves by a slender beginning.

‡ Bellingeri (De Medulla Spinali, Nervisque ex ea Prodeuntibus, p. 74, 1823,) adopts the description of Huber where he states that it commences opposite the seventh.

§ Oper. cit. p. 51 and 55. See also Edin. Med. and Surgical Journal, Vol. xliv. p. 396.

spinal accessory, when present, rarely come from the second, but generally from the first cervical. When they come from the posterior root of the second cervical, they are few in number. Those from the first cervical vary considerably in number; for we find sometimes a few, sometimes the greater part, at other times the whole of the filaments of this root passing to join the *spinal accessory*. This junction between these two nerves may be confined to one side of the spinal chord, or it may be present on both. This communication between the *posterior root* of the first cervical and the *spinal accessory* is far from being rare, and Lobstein asserts that it is more frequently present than absent.* When the posterior root of the first cervical joins itself to the *spinal accessory*, a branch of equal size leaves the trunk of the *accessory*, either at the point where it is joined by the posterior root, as figured and described by Asch, † or from three to six lines above this junction, as figured by Huber,‡ and described by Bellingeri. § This branch, after leaving the accessory, proceeds outwards, approaches the anterior root of the first cervical, and takes the place of the posterior root. When the posterior root of the first cervical comes from the *accessory*, it generally swells into a ganglion in the usual position. Sometimes, however, though rarely, a ganglion is found where the posterior root leaves the *accessory* to join itself to the anterior root. This ganglion was first pointed out by Huber, and its existence has been denied by Lobstein, Asch, Haller, and Scarpa, and has again been described by Bellingeri. I have seen this ganglion once, and it was present on one side only. It becomes an interesting question, to know whether or not the whole of the filaments joining the *accessory* from the posterior roots of the *spinal nerves*, leave it again to form the posterior root of the *first cervical*. Bellingeri answers this question in the affirmative.—"The filaments coming from the posterior roots to the accessory are not intermixed, but only approximated, so that they can be separated by slight traction." ‖ And in another place he says, "I believe that the filaments from the posterior roots which join the accessory, leave it again to proceed to the posterior root of the first cervical." ¶ From this he concludes that this nerve contains no sensitive filaments. Müller ** adduces some unusual appearances in this nerve, observed by Hyrtl, Remak, and himself, which would seem to favour the opinion, that it contains some sensitive filaments, inde-

* In speaking of the filaments which form this communication he says, "communicationem illud notamus quod sæpius accessorium subire quam eundem intactum relinquere observentur."

† De Primo Pare Nervorum Medullæ Spinalis. Tab. x. fig. ii. et Explicatio, p. 335. Ludwig, Sc. Nerv, Min. Sel. Tom. i.

‡ Oper. cit § Ibid. p. 80. ‖ Ibid. p. 81. ¶ Ibid. p. 79.

** Arch. für Anat. und Physiol. No. ii. 1837.

pendent of those which it occasionally receives from the posterior roots. "I do not, however, affirm," he says, "that the spinal accessory always contains a sensorial element, but leave it doubtful."—"But in the case," he continues, "where the *nervus accessorius* forms an intimate connection with the posterior root of the first cervical or any other nerve, we may suppose an interchange, and this in the same degree will render probable the idea of Monro, that the communication of the spinal accessory with the posterior root of the first or any other spinal nerve will be an equivalent to it for a posterior root."* The only other point connected with the anatomy of this nerve to which we shall here refer, is its connection with the *par vagum*, for we shall have occasion to allude to it repeatedly, when examining the functions of this nerve. As the spinal accessory is passing through the *foramen lacerum* it divides into two branches,—an internal and an external. The internal, after giving off some filaments to assist in forming the pharyngeal branch of the *par vagum*, becomes incorporated with the filaments of the trunk of the *nervus vagus*. The *nervus vagus* swells into a ganglion (*ganglion secundum nervi vagi*,) where it is joined by the internal branch of the accessory, and by branches from the sympathetic. This ganglion is very distinct in the lower animals. Bischoff † states that he ascertained by dissections of the Mammalia that only a part of the fibres pass into the ganglion, and that the others retain their fibrous character. He also adds, that it is evident that those which form the ganglion belong to the *par vagum*, while those which do not enter into its formation belong to the internal branch of the accessory. From this gangliform swelling the superior laryngeal nerve arises.‡ The *external branch* proceeds outwards, perforates the upper

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* Oper. cit, p. 279. † Ibid. p. 22.

‡ Since the above remarks were written out, I have seen it announced in a paper by Mr E. Cock, in Guy's Hospital Reports for October 1837, that Sir Astley Cooper has discovered a new ganglion in the rabbit, which he terms the superior laryngeal ganglion. This, however, is obviously the *second ganglion* of the par vagum of some anatomists. It appears that Sir A. supposed, before he discovered this ganglion, that the superior laryngeal nerve furnished an objection to the opinion of Sir C. Bell, that all nerves of common sensation are provided with ganglia. But Sir A. seems to have forgotten that there is a true ganglion of the par vagum as it lies in the foramen laeerum. This superior ganglion of the vagus was known to Ehrenritter, figured by Wutzer, (De Corporis Humani Gangliorum, Fab. et Usu, Fig vii. 1818,) redescribed by Arnold, (Der Kopftheil des vegetativen Nerven-Systemes, p. 105, Heid. 1831); also particularly described by Bischoff, (Nervi Accessorii Willisii, Anat. et Physiol. p. 21, 1832); and now admitted by every anatomist who has examined it. The second ganglion of the par vagum, which Mr Cock thinks an entirely new discovery on the part of Sir Astley, has also long been known. It has been described by Vieussens, Willis, Scarpa, and others. It is figured by Wutzer (Oper. cit,) as the second ganglion of the par vagum. Bischoff, after stating that Arnold names this swelling upon the par vagum a gangliform plexus, thus expresses himself: "Verum apud mammalia dubito an argui possit hunc tumorem non reapse ganglion esse. In universum proportione in his bestiis multo crassius est quam

part of the *sterno-cleido-mastoideus*, sends filaments to this muscle, and to the *trapezius*, and forms at the same time several anastomoses with branches from the *cervical plexus*. The peculiar origin and course of this nerve, and particularly its intimate connection with the *par vagum*, have formed the basis of most of the speculations on its functions since the time of Willis. It was maintained by Willis,* that this nerve, from its connection with the *par vagum*, regulated those involuntary movements of the neck and arm connected with the emotions and passions. Lobstein also believed that the spinal accessory joins itself to the *nervus vagus* for the purpose of connecting it with the involuntary functions, † and he supposed that paralysis of this nerve might also affect the movements of the *pharynx* and *larynx*.‡ Others have maintained that it is a nerve of involuntary motion, from the particular portion of the spinal chord from which it arises. It is, as is well known, one of Sir C. Bell's respiratory nerves, arising, as he supposes, from a particular tract in the spinal chord. According, then, to Sir C. Bell, it is a nerve of involuntary motion. Bellingeri believes that the lateral tract of the spinal chord from which the accessory arises, presides over the instinctive and sympathetic movements, and consequently this nerve must be one of involuntary motion.§ Arnold,‖ Scarpa,¶ and Bischoff,** maintain that the accessory stands in the same relation to the *nervus vagus* which the anterior roots of the spinal nerves do to the posterior.†† These nerves, as they lie in the *foramen lacerum*, do certainly resemble very closely in appearance, the anterior and posterior roots of the spinal nerves. The junction of the internal branch of the accessory with the *par vagum* beyond the part where it swells into its superior ganglion increases the resemblance still farther. To this opinion we shall have again to refer. With these preliminary remarks I shall now proceed to give the results obtained from my experiments on this nerve.

Effects of Irritating this Nerve in the Living and recently killed Animal.—These experiments on the living animal were performed on the external branch of the *accessory* before it per-

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in humano corpore et simillimum sæpe est ganglio cervicale supremo Sympathetici quod situm est aut supra aut juxta aut infra illud vagi ganglion." (Oper. cit, p. 22.) In Tab. ii. he gives some very excellent engravings, in which the position and form of this second ganglion of the par vagum, and the origin of the superior laryngeal from it are represented in the cat, fox, sow, mole and weasel.

* Cerebri Anatome, &c. Cap. xxviii.

† Oper. cit. 346.

‡ Oper. cit. 345.

§ Oper. cit. p. 89–90.

‖ Der Kopftheil des vegetativen Nerven-Syst. Heidel. 1831.

¶ De Gangliis Nerv. deque Essentia Nervi Intercost. Ann. Univers. de Medicine, 1831.

** Oper cit.

†† It appears that this idea had been previously stated by Görres, (Exposition der Physiologie. Coblentz, 1805.

forates the upper part of the *sterno-mastoid*, as it is impossible to operate on the trunk of the nerve unless it is exposed within the cranium. Irritation of this nerve by the forceps in the living animal produces vigorous convulsive movements of the *sterno-mastoid* and *trapezius*, as was remarked by Dr M. Hall and Mr Broughton in their experiments.* This mode of irritating the nerve is not attended by any indications of suffering, unless the nerve is strongly compressed between the blades of the forceps. When the nerve is firmly included in a ligature, the animal gives very decided evidence of suffering pain. When the nerve has been firmly tied or cut across, irritation of the lower end is attended by the same convulsive movements of the muscles, while irritation of the upper end, or that in connection with the *spinal chord*, is unattended by any muscular movements. The same muscular movements are observed on irritating the nerve in the recently killed as in the living animal. From these experiments we conclude that the filaments of the *external* branch of the *spinal accessory* are principally motor, and that the sensitive filaments must be very few in number. Whether those sensitive filaments belong originally to the nerve, or whether it derives them from the other nerves at the base of the cranium, with which it anastomoses, we cannot at present determine.

Effects of the Division of these Nerves.—According to Sir C. Bell, the section of the *spinal accessory* paralyses the muscles to which it is distributed, as muscles of respiration, though they still retain their voluntary movements through the media of the spinal nerves. This appears to be established by the following experiment performed by Mr Shaw. "The *par vagum* of an ass was first divided, with the intention of causing difficult and laboured respiration. When all the respiratory apparatus was in great agitation, and when the sterno-maxillaris (the same as the sterno-cleido-mastoideus in man) was especially in action, the spinal accessory was divided. In an instant the sterno-maxillaris ceased to act as a muscle of respiration, but when the animal struggled to get free, it became rigid, showing that through the plentiful supply of spinal nerves it still retained its office of moving the head and neck."† That part of the experiment which relates to the cessation of the respiratory movements of the *sterno-maxillaris* being a negative observation, ought, we think, to have been repeated and further confirmed, before such important conclusions were drawn from it. I have removed a portion of the external branch of this nerve on one side as it issues from the foramen lacerum in seven dogs, without observing any change upon

* Fourth Report of British S. Association.

† London Medical and Physical Journal, Vol. xlix. p. 459.

the ordinary voluntary movements of that side of the neck. It is possible, however, that if the animals had any violent voluntary efforts to make with the muscles of the neck, that those of the side on which the nerve had been cut might have acted less vigorously than those of the opposite side. I then proceeded to endeavour to ascertain the effects of the section of this nerve upon the involuntary respiratory movements of these muscles. The experiments were performed on dogs and cats.

The plan which I followed appears to me to be more likely to lead to accurate results than that adopted by Mr Shaw. In the method followed by Mr Shaw the animal might use these muscles voluntarily when the breathing was rendered difficult, and therefore lead to erroneous conclusions. Besides, the difficulty of recognizing the movements of any particular muscle through the skin of the animal, (at least in the kind of animals I operated on,) when so many other of the neighbouring muscles are in movement, must also be apt to mislead. The plan which I adopted was this. A small dose of prussic acid was given to an animal on which the spinal accessory had been previously divided on one side. After the convulsive movements produced by the effects of the acid had ceased, the animal was generally found in a state similar to what we sometimes see in apoplexy,—the action of the heart went on, and the respiration was slow, heaving, and performed at considerable intervals, while the sensorial functions appeared to be completely suspended. The animal had undoubtedly lost the power of making the slightest voluntary effort. The respiratory movements always ceased before the action of the heart, but they continued in several of these animals sufficiently long to permit us to lay bare all the muscles of the anterior part of the neck, and to make accurate observations. The *sterno-mastoids* in dogs and cats appear to have little action as respiratory muscles; for in some of these experiments, though the *sterno-hyoid* and *thyroid muscles* acted very powerfully in unison with the other muscles of inspiration, and the head was pulled towards the chest at each inspiratory movement, yet no contraction could be perceived in the *sterno-mastoid*, neither in the side on which the nerve had been cut, nor on that on which it had been left uninjured. In one dog, distinct muscular movements were observed in a bundle of muscular fibres, which arise from the humerus, run up along the outer margin of the *sterno-mastoid*, and are inserted along with it. This muscular bundle receives filaments from the *accessory*. In two dogs and one cat in which the head was fixed, and where these respiratory movements were particularly vigorous, distinct movements of contraction and relaxation were observed in the exposed *sterno-mastoid* muscles, synchronous with the other muscles of respiration. These were, perhaps, somewhat weaker on the side on which the nerve

had been cut. In one of these dogs similar movements were observed in the *trapezius* on the side on which the nerve had been divided. From these experiments we conclude, that the *sterno-cleido-mastoideus* and *trapezius* can assist in the involuntary movements of respiration after section of the *spinal accessory*, and therefore it cannot be called the special respiratory nerve of these muscles. As far as we can observe, the functions of the external branch of the *spinal accessory* exactly resemble those of the filaments coming from the *cervical plexus*, with which it anastomoses so freely. Future anatomical researches may perhaps explain to us how it follows this peculiar course, without obliging us to suppose that it has a reference to any special function in the adult of the human species.

We now proceed to inquire what are the functions of the *internal branch* of the spinal accessory? We have already stated that Arnold, Scarpa, and Bischoff have imagined that the spinal accessory stands in the same relation to the *par vagum*, as the anterior roots of the spinal nerves do to the posterior. If this view be correct, the *internal branch* of the *accessory* must furnish the motor filaments of the *par vagum*, and upon it must depend the important muscular movements of the pharynx, larynx, and œsophagus. As no anatomist has yet succeeded in tracing for any great distance the filaments of the accessory, separate from those of the trunk of the *nervus vagus*, it is therefore impossible to decide this question satisfactorily by the anatomy alone of the nerves.* Bischoff proceeded to submit this opinion to the test of experiment, by endeavouring to ascertain what effects section of the trunk of the accessory within the cranium would have upon the voice. After relating several failures upon dogs, in which the animals either died from hemorrhage before the nerves could be fairly divided, or when they did survive the operation, it was afterwards found that the superior filaments of the nerve were left uncut; he informs us that he at last succeeded in performing the experiment in a satisfactory manner upon a goat. He states that it was remarked in this experiment, that, as the roots of the accessory nerves were cut, the voice became gradually weaker, and when the last filaments were divided it became completely lost. † It

* Since this was written I have seen in No. iii of Müller's Archives for this year (1837,) an epitome of the investigations of Bendz, "De connexu inter nervum vagum et accessorium." From these dissections, it is concluded (Jahresbericht, &c. in Jahre 1836, p. xxv.) that both in man and animals, the *nervus pharyngeus* of the *par vagum* is derived in a great part from the filaments of the accessory, and that the *nervi laryngi*, *superior* and *inferior*, and the *œsophageal plexus* also receive a *few* filaments from this nerve. He has also observed the accessory in man, (p. xxiv.) furnish a few filaments to the second ganglion of the *par vagum*. Into this second ganglion of the *par vagum* all the filaments of the vagus do not enter. He has even seen in the rabbit some of the filaments of the vagus pass the superior ganglion placed on this nerve, without entering into its formation.

† Oper. cit. p. 94.

must, however, be apparent, that one negative experiment of this kind can never be adduced as satisfactory evidence of the dependence of the movements of the *larynx* upon the *spinal accessory*. There were here other causes in operation which might suspend the power of emitting sounds besides the section of the roots of the *accessory* nerves, and the simultaneous occurrence of the complete loss of voice, and the section of the last roots of the *accessory*, might not have stood to each other in the relation of cause and effect, but as a mere coincidence. The escape of the cerebro-spinal fluid, the unavoidable loss of blood, the exposure of the *medulla oblongata* to the external air, and the protracted pain and struggles of the animal, are more than enough to induce a state of stupor and debility sufficient to suspend its cries. In two attempts to repeat this experiment upon a dog and a cat, the animals died from hemorrhage before the nerves could be fairly exposed and divided. I then determined to try the effects of irritating these nerves within the cranium on an animal recently killed. I find that this method had been previously followed in one experiment by Müller. * In this experiment he ascertained that irritation of the *nervus vagus* within the cranium, both mechanically and by a single pair of galvanic plates, produced contraction of the *œsophagus*. As I was not aware that such an experiment had been made until I had completed those which I am about to mention, I could not be influenced in my observations by the authority of this very distinguished physiologist and accurate observer. I performed my experiments in the following manner. The animal was deprived of sensation by a dose of prussic acid, and the cranium was then opened as rapidly as possible. As soon as the nerves were exposed, the parts in the neck, which it was wished to observe during the irritation of the nerves, were quickly laid bare. The nerves were insulated from each other, and the animal was so placed, that while Dr Duncan and Mr Spence irritated the nerves, I could watch the effects upon the parts exposed. Some of the experiments failed from the facility with which these nerves are broken within the cranium, and from the enfeebled state of the muscular contractility, from the length of time required to go through all these preparatory steps. We procured, however, some results which I consider sufficiently satisfactory as far as they go. In one experiment, in which the *spinal accessory* was irritated by galvanism, when the aperture of the *glottis* was exposed, powerful convulsive movements of the shoulder were observed, but not the slightest movements of the muscles of the *glottis*. In another dog convulsive movements of the pharynx accompanied the convulsive twitches of the shoulder. In one dog in which irritation of the *spinal accessory* had produced powerful

* Handbuch, &c. Erster Band, p. 641.

movements of the shoulder, the nerve was broken within the *foramen lacerum*, on attempting the irritation after the *glottis* was brought into view; the galvanic wires were then applied to the par vagum, and a distinct though feeble movement of the *arytenoid* cartilages followed, *unattended by any movements of the shoulder*. In another dog, a distinct movement of the *pharynx* and *arytenoid* cartilages followed the pinching of the insulated *par vagum* with the forceps. I attach most importance to this last experiment, as it is difficult in some cases to be quite certain that the galvanic influence is confined to the nerve operated upon, when others are placed in the immediate neighbourhood. From those experiments we think there can be no doubt that the trunk of the *par vagum* contains within it *motor* filaments independent of those which it receives from the *internal* branch of the spinal accessory. That the internal branch of the spinal accessory assists in moving the muscles of the pharynx we are satisfied, not only from the experiments just stated, but also from those upon the pharyngeal branch of the *par vagum*. Of the probable destination and functions of the other filaments of the *internal* branch of the *accessory*, we cannot pretend to judge without more extended inquiries. We certainly do not consider that these experiments entitle us to assert that they are not motor filaments.*

I may here state, that the arguments adduced from comparative anatomy, in favour of the opinion, that the spinal accessory is solely connected with the involuntary respiratory movements, may be considered as completely controverted by late researches. Serres has discovered its existence in some birds; Weber in some fishes; and Bischoff in birds, fishes, and reptiles.

These experiments upon the glosso-pharyngeal and spinal accessory have furnished results in direct opposition to the respiratory system of Sir C. Bell; for certain supposed functions of these nerves have been considered as forming one of the principal strongholds of that ingenious and plausible theory. I think there can be no doubt, that the distinguished discoverer of the distinct functions of the anterior and posterior roots of the spinal nerves, has taken a very limited and partial view of the sympathetic movements of the body, when he framed his respiratory system. His attention appears to have been so entirely absorbed by those connected with the respiratory function, that he seems to have forgotten that there are other extensive associated and sympathetic movements of the muscles of the body, besides those which he has so beautifully illustrated. For it is obvious, that, if a particular tract of the spinal chord is necessary to carry on the respi-

* The dissection of Bendz, to which we have already referred, seem to show that these filaments of the accessory are distributed upon the larynx and œsophagus. They therefore probably assist in the movements of these parts.

ratory movements, there ought also to have been a defecatory tract, a urinary tract, and so on, to carry on the other sympathetic movements in which a number of distant muscles are engaged in simultaneous action. If the other associated movements can go on without it being necessary that the nerves supplying the muscles engaged in these, should come from particular tracts of the spinal chord, then surely there can be no necessity for this in the case of the respiratory nerves. The insufficiency of Sir C. Bell's theory to answer the ends proposed has been pointed out in a most satisfactory manner by Dr Alison in his elaborate essay on Sympathy.* It appears to me that physiologists have been exceedingly premature in framing new systems of nerves to carry on the sympathetic and instinctive movements of the body. For I believe that it will be found, that all the nerves of the body which can transmit the influence of volition can also transmit the influence by which the muscles they supply are called into sympathetic movement, and that the reason of some muscles being called more frequently into sympathetic action than others, does not arise from any difference in the nerves supplying these muscles, but from a difference in the circumstances under which they are placed. We term the muscles of the extremities muscles of strictly voluntary motion, though we admit that when a person is falling forwards, the arms are instinctively thrown in front,—in other words, some of these muscles contract without our volition, and through means of an influence sent along the same nerves by which they are called into voluntary action. In the same manner, when the foot of an infant is pricked, the leg is instinctively drawn upwards; and the involuntary start of surprise is sufficient to show that the respiratory are not the only muscles of the trunk which are involuntary in their action. The respiratory muscles are said generally to be partly voluntary and partly involuntary; but it appears to me perfectly obvious, that they are as much muscles of voluntary motion as those of the extremities, and that the reason of their so frequently receiving the name of involuntary arises from this, that, though properly voluntary, they are so much more frequently called into action by impressions accompanied by sensations than other voluntary muscles, that this has attracted the attention of physiologists to them in particular. We have seen that the muscles of the extremities (which every one calls muscles of strictly voluntary motion, to distinguish the mode by which they are stimulated to contraction, from that of the heart and muscular coat of the intestines,) perform associated movements without our volition on the excitation of certain impressions and sensations, and they obviously differ in no respect

* Edinburgh Medico Chirurgical Transactions, Vol. ii.

from the muscles of respiration, except in the relative frequency with which those involuntary movements are performed. This difference in the relative frequency of the action, again, evidently depends only upon the circumstances under which they are placed; for it is absolutely necessary for the preservation of the individual that the impressions arising from the want of fresh air in the lungs be frequently and regularly repeated, while the other sensations to which we have referred can be only occasional and accidental. It is obvious from these remarks that we do not object to the application of the term, muscles partly of voluntary and partly of involuntary motion, on account of its want of correctness, but because it is apt to mislead, for it may either induce us to believe that these respiratory muscles have at times some analogy in their mode of excitation to the heart and muscular coat of the intestines; or, what is more likely, that there is something specifically different between the nerves by which they are stimulated to contraction, and those distributed upon the muscles of the extremities. We believe that there are no muscles in the body which do not also sometimes deserve the name of involuntary, though the relative number of their involuntary movements may be far inferior to the strictly voluntary. If these views be correct, there appears to be nothing so peculiar in the action of the respiratory muscles, that they should require any distinct set of nerves.* How, or in what manner the influences of volition and of certain impressions and sensations are invariably directed along certain motor nerves in preference to others, is at present and probably ever will be, an utter mystery. The ends for which these sympathetic and instinctive actions were designed are obvious, but we have not been able to perceive any particular structural arrangement of the nervous system specially connected with their manifestation.

Though the sensitive and motor filaments of the spinal nerves appear to be separate from each other, and arise from distinct tracts of the spinal chord, yet it is not so with those arising from the upper part of this chord; and there appears to be some blending together of the motor and sensitive tracts of the spinal chord, when continued upwards into the *medulla oblongata*, which we cannot at present fairly explain. To say nothing of the *portio*

* I do not mean to deny, that it is possible that the motor filaments for transmitting the influence of volition may be distinct from those which transmit that sympathetic influence by which muscles are called into action in obedience to impressions made upon distant parts, and that those two sets of filaments may be bound up intimately together in the nervous chords distributed upon the muscles of the trunk and limbs. Since, however, we have no direct facts to guide us in a speculation of this kind, it is surely worse than useless to enter upon it. What we maintain is, that the *nervous chords* supplying all the muscles of the trunk and extremities, are capable of transmitting both the influence of volition and of sympathetic movement; and that, therefore, there is no specific difference between the nervous filaments supplying the muscles of respiration and those of the extremities.

dura and fourth pair, we find the *glosso-pharyngeal, par vagum*, and *spinal accessory* arising in the same line from the middle column of the spinal chord, and yet the filaments contained in these three nerves are partly sensitive, and partly motor; for no one can deny that the muscles of the *glottis* can and do frequently act from volition. It is possible that some of those motor filaments are furnished by the band of fibres which Mr Solly * has lately described as passing across from the anterior column to the *crus cerebelli*. A good deal evidently still requires to be done, before we can expect any satisfactory elucidation of the anatomical arrangement of these columns of the spinal chord, and their relations to the different nerves attached to them. We find, for example, Bellingeri and Sir C. Bell, two of the latest and best authorities on this subject, differ with regard to the origin of the posterior roots of the spinal nerves; for while Bellingeri † describes these posterior roots as arising partly from the posterior column, partly from the grey matter in the posterior collateral groove, and partly from the middle or lateral column, Sir C. Bell has renounced his former opinion, that they come from the posterior column, and now describes them as arising from the middle column. ‡

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* On the Human Brain, &c. † Oper. cit. p. 69.

‡ On the Nervous System, p. 234 and 238, edit. 3d. Sir C. however, adds in a note, p. 234, that it is not impossible that the posterior column may be connected with the sensitive root of the spinal nerves, though he has not hitherto succeeded in tracing it.

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